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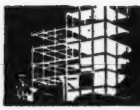

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Do You Know—

▶ You will be interested in the following resume of current activities of two of our Councils—the Engineering College Research Council and the Engineering College Administrative Council. Both Councils have been exceptionally active during the past year and have in progress some studies of considerable importance to the Society and to engineering education.

▶ The Engineering College Research Council—Dr. H. K. Work, Vice President—is undertaking again this year to make a comprehensive tabulation of research projects in engineering colleges throughout the country in preparation for publication of the ECRC *Review of Current Research*. This volume has proven of inestimable value to government agencies, to industry, and to the engineering colleges in helping them to identify institutions which have particular research capabilities.

▶ The ECRC is currently considering the possibility of establishing an award to provide recognition and incentives for distinguished research, achievements and contributions to the administration of research.

▶ The ECRC has completed a study on Remuneration Policies in Research. This deals with some of the knotty problems in research administration, such as, should a faculty member who is carrying research on an overtime basis receive supplementary compensation? The results of this survey will be published in a forthcoming issue of the JOURNAL.

▶ Also, may we call your attention to the statement on research policy published in the October issue of the JOURNAL? This was a carefully formulated policy statement of the need and objectives of research in engineering colleges.

▶ ECRC is currently planning a publication, *Creativity in Research*, including a number of exceedingly interesting papers on this subject presented at the ASEE Annual Meeting at Urbana and also at the joint meeting of ECAC–ECRC in the fall of 1953. This is a lively subject and one which merits thoughtful attention.

▶ A committee of ECRC has been doing an outstanding job of keeping research directors and deans appraised of current government policies with respect to the administration of government sponsored research. Government policies vary widely, hence the strategic importance of this service. Dean Erie Walker, the retiring ASEE Vice President and his ECRC Secretary, Virgil Neilly, have contributed a great deal of stimulus to the ECRC program during the past two years.

▶ The Engineering College Administrative Council—W. L. Everitt, Vice President—has vigorously undertaken a number of important new projects during the past year. An interesting project which ECAC is struggling with, and one which shows considerable promise, is a study of problems involved in getting work experience for foreign students in this country. Because of security regulations, social prejudice, language difficulties, and other factors, it is extremely difficult for foreign students to get work experience in American industry. Yet, this is one of the most valuable experi-

ences which they can obtain. There is no simple solution to this problem, but it is one deserving of careful study.

► The ECAC has been of considerable help to the Foreign Operations Administration of the U. S. State Department in advising them on cooperative arrangements which they might make with American engineering colleges in a joint effort to obtain technical assistance for underdeveloped countries of the world, particularly on problems relating to engineering education and research.

► The Manpower Committee of ECAC is continuing to work with the Engineering Manpower Commission on studies of the current status and trends of Manpower.

► During the past year, the Military Affairs Committee of ECAC conducted two studies on important current problems. One of these studies was to determine the viewpoint of deans of engineering colleges as to the desirability of protesting abrupt changes in airforce regulations governing the awarding of commissions. The second was a study to determine the viewpoint of the deans with respect to the Army ROTC move toward the Branch General Program. Both of these studies helped to clarify the issues involved in ROTC programs.

► The ECAC has just recently completed a study of engineering faculty salaries, using statistics collected by the Engineers' Joint Council. The report is published in this issue of the JOURNAL.

► The ECAC Committee on Secondary Schools has been working on a program of articulation of high school and college educational programs, with a view toward getting secondary schools to recognize the importance of this problem.

► The Selection and Guidance Committee of ECAC has been working actively with the Educational Testing Service in devising tests to assist engineering graduates to determine their individual aptitudes. These tests will also be helpful to industry in placing graduates in positions for which they are best qualified.

► The ECAC has been considering some problems relating to financial support for engineering including industry's viewpoints toward various kinds of college programs which might merit financial support. Another phase of industry-college cooperation which the ECAC is currently studying is that of exchange programs between industries and colleges, making it possible for college teachers to obtain employment in industry.

► No review of ECAC–ECRC activities would be complete without mention of the very stimulating Fall Meeting in 1953, dealing with the general theme of Creative Thinking in the Arts, in Literature, and in Engineering, or of the Joint Dinner of ECAC–ECRC which highlighted their activities at the Annual Meeting at Urbana, featuring Dr. Lee DuBridge.

► Plan now to attend the next Annual Meeting, June 20–24, 1955 at Pennsylvania State University. We'll see you there.

Respectfully submitted,
ARTHUR BRONWELL, *Secretary*

Relations with Regional Accrediting Associations*

By HAROLD L. HAZEN

Dean of The Graduate School, Massachusetts Institute of Technology

In a companion paper the principles and operations of the ECPD Accreditation Program were presented in some detail. However, ECPD is not alone in this accreditation field, as our associates in university administration are quite aware, and this has implications for the ECPD program. It appears indeed that accreditation of curricula at the college level has become a popular indoor sport that threatens to involve college presidents in a full-time activity. Surprisingly enough, college presidents are under the illusion that they have a certain minimum of other obligations and have shown signs of rebellion at what in the vernacular might almost be called a "racket."

More seriously, the threatened limitations imposed on a university by the great number of organizations claiming accreditational jurisdiction, by the quite arbitrary and unreasonable criteria that are sometimes applied to determine accreditability, and most seriously, by the resulting threat of unhealthy restraint upon educational experimentation and upon the response of the institution to its own peculiar objectives and intrinsic institutional character, are very real. In combination they have caused a rebellion against accreditation on the part of many institutional heads as expressed in the National Commission on Accrediting.[1]

The apparent abuses and unhealthy restraints had reached such proportions that the initial objective of NCA was very simple: eliminate accreditation. The radical character of this step is perhaps a significant measure of the degree of provocation involved. Subsequently the legal needs for accreditation in certain fields were recognized, as were the vast differences between the provocative, and indeed almost blackmail policies of certain proprietary groups on the one hand, and on the other hand, the work of responsible agencies of some of the professions, attempting to assure on behalf of the public a minimum standard of educational experience as preparation for a professional career. The next step was to attempt to achieve relief from what had become excesses in the accreditation activity as a whole, and to relieve the institutions from the undue demands for time and work by achieving a simplification of procedures and consolidation of efforts.

Thus during the year 1952 it was suggested that the so-called "regional associations" of colleges and universities be assigned the responsibility on behalf of

*Presented at the ECAC Conference ASEE, June 16, 1954, University of Illinois.

[1] The paper by Dr. Ewald B. Nyquist, Chairman, Commission on Institutions of Higher Education, Middle States Ass'n of Colleges & Secondary Schools, "National and Regional Developments in Cooperative Evaluation and Accrediting Activity," JOURNAL OF ENGINEERING EDUCATION, Vol. 44, No. 9, May 1954, pp. 533–538, describes the National Commission on Accrediting. It also treats regional and professional accrediting agencies and their interrelations, but with different emphases, such that the Nyquist paper and this paper are complementary rather than overlapping.

NCA for simplification and rationalization of the accreditation activity on the part of at least those professions in whose practice the public welfare and safety are involved. The regional associations were therefore thought of as a coordinating agency under which possible cooperative and collaborative operation with the accreditation agencies of certain professions might be developed.

At this point, the Middle States Association of Colleges and Secondary Schools, being the regional association with the most fully developed accreditation activity, proceeded to accelerate the process of its development along the foregoing lines. Since 1947, this Association had made institutionwide evaluations employing at appropriate times representatives from the whole professional galaxy; until 1952, however, the Middle States Association had not entered into formal cooperative agreements with professional accrediting agencies. The Engineers can, perhaps, take justifiable pride as the first professional group to consummate an agreement which would in practice explore this new collaborative principle.

During the winter of 1952–53 representatives of the Middle States Association and ECPD held a number of exploratory sessions, during which the possibilities of collaboration appeared sufficiently promising to justify an experimental operation on an actual institution. A combined questionnaire was devised and tentative agreement reached upon the roles that representatives from the two agencies would play and the reporting responsibilities of the two groups.

Differences in Function

Here it is appropriate to delineate the differences in function and in accreditation procedures of the Middle States Association and ECPD.

The objectives of the Middle States Association program can perhaps best be stated in terms of a few sentences extracted from its "Standards for Accreditation" adopted November 1950. I shall try to pick these few sentences from a several page text in such a way as to avoid as far as possible distortion of meaning through omission of context:

> The Middle States Association of Colleges and Secondary Schools is a membership of educational institutions joined for mutual encouragement and helpfulness. . . . The Association, through its Commission on Institutions of Higher Education, maintains a list of higher institutions that have been evaluated and found qualified for membership in the Association. An evaluation for initial accreditation is made at the voluntary request of the institutions seeking the approval of and membership in the Association. . . .
>
> The Commission believes that a fundamental criterion of excellence in an institution is found in the extent of the awareness of all concerned with it, of its place and importance in relation to its students, its supporters, and the community at large. . . .
>
> The deciding factor in the determination of whether any institution is qualified for membership in the Association is evidenced by the extent to which that institution fulfills the objective it has set for itself. . . .

MSA approves or disapproves the institution as a whole. It reports to the institution on the strengths and weaknesses found in the inspection. It may, for example, approve an institution for membership in spite of certain weak areas, provided the institution as a whole is achieving a reasonable degree of success in attaining its declared objectives.

As we know, the objectives of ECPD inspection are somewhat different. The objective of ECPD is to determine whether certain specific curricula individually submitted by the institution for ECPD appraisal meet the minimal standard for educational opportunity offered to students receiving its first degree in engineering.

A principal objective of MSA is the rendering to the institution of a comprehensive report on its observations of the institution's operations. This includes sections specially prepared by ECPD in

accord with MSA objectives on the engineering school as a whole, including, for example, any graduate, or non-degree work offered. The ECPD full reports, on the other hand, apply only to the curricula submitted for accreditation, and are confidential with the inspection committee, the Education Committee, and the Council of ECPD. The institution receives an official notification of ECPD action on the curricula submitted for inspection, together with a brief statement of observations by the visiting committee. The president is told that he may obtain a somewhat fuller statement upon request to the regional chairman.

As a result of the joint planning of MSA and ECPD and concurrence by the college, an experimental joint and collaborative visit was made in March 1953 to an institution that from the point of view of number and range of objectives was fairly simple in contrast, for example, to a full university. This experiment was considered a success and set the pattern for several subsequent collaborative inspections. Some of these involve much more complicated institutions and included accreditation groups from a number of other professions in addition to engineering.

The Middle States Association team includes members of recognized standing in their fields from sister institutions who are professionally active in essentially every phase of the activities of the institution being visited. It will therefore include such persons as a college president, a fiscal officer, a librarian, a superintendent of buildings and grounds, an athletics director, an admissions officer, perhaps a dean of students, a graduate dean, and in addition one or more professors or deans for each of the principal academic departments or units within the institution being visited.

The ECPD members of the visiting team perform in a dual capacity. On the one hand they do essentially the same job that they would do if they were visiting the institution alone, particularly with respect to the major engineering departments for which the institution has requested ECPD examination. On the other hand, the ECPD members function also as members in full standing of the MSA team, supplying to MSA its entire appraisal of the engineering departments. The MSA visitors in turn, either alone or in some cases jointly with ECPD members, visit and supply an appraisal to ECPD of such fields as the Humanities and Social Sciences, the basic sciences, Administration, Library, Admissions, and other areas supporting the engineering activity.

Broader Foundation of Expert Appraisal

From the point of view of ECPD this collaboration provides a substantially more thorough and expert appraisal of the non-engineering aspects of the institution's operations than ECPD alone would obtain. In a collaborative visit the ECPD team can therefore concentrate more attention on those areas in which it is expert. Thus the ECPD recommendations from such a collaborative visit have a substantially broader foundation of expert appraisal than would otherwise be available.

On the other side, some time of ECPD team members is spent in the executive sessions held each evening to review the progress of the appraisal on matters that have minor relevance to ECPD objectives. On the whole, however, it appears that the collaborative procedure provides a foundation for judgment as to the adequacy of the engineering curricula that is substantially broader than that provided by an isolated ECPD operation.

The combined questionnaire answered by the institution has two parts: the first, Part A, is general, applying to the institution as a whole, its policy, administration, budget, promotion and retirement plans, etc. The second, Part B, relates specifically to the professional area involved, in the case of ECPD, to engineering. This more comprehensive

questionnaire, all of which is available to every member of the team including ECPD members, provides much more comprehensive information, and simultaneously a fairly large amount of material not directly relevant to ECPD appraisal. The combined questionnaire presumably does offer some saving in time and effort to the institution.

In the case of a large and complex institution such as a university, a collaborative visit, including the regional association, plus as many as a dozen or two professional agencies, yields a large and potentially cumbersome group to do business in executive session. Thus far such a group, which has amounted to as many as 60 persons, has not proved unmanageable, but it is believed that continued examination of the mechanics of an inspection can result in a more efficient use of everyone's time.

While it is too soon to draw conclusions, it appears that this collaborative procedure is well worth further development. It appears to work well in the case of relatively simple institutions. It works well, but perhaps less efficiently in the case of very complex institutions. It probably saves the institution time, effort, and consequently money.

It is, I believe, generally recognized that of the regional associations the Middle States Association has developed its accreditation program much further than the others. It has an experienced, well organized, and smoothly functioning organization for this purpose, The Commission on Higher Education.

This operation is of necessity costly, simply because it is a comprehensive and thorough job. However, the costs for an institutionwide evaluation under collaborative procedures are very little if any more than if all of the professional agencies and the Middle States Association went their separate ways. The costs are perhaps more obvious since they all come at one time, not on the installment plan, as it were, but their annoyance value may be less. Direct costs can be estimated as to order of magnitude in terms of a few to several tens of people traveling to and living at an institutional location for three or four days.

Some of the other regional associations have had relatively little experience in this type of operation, and their memberships apparently do not have enthusiasm for as thorough and consequently as costly an operation as is accepted by members of the Middle States Association. How collaboration on the part of ECPD will function in a substantially less well developed activity is an open question. This is one of the current problems.

Larger Issues

There are also some larger issues that are far from completely resolved. Some institutional presidents quite rightly feel that they, with the support, counsel, and guidance of their Boards of Trustees and of their faculties, have the ultimate responsibility for the welfare and character of their institution. As a result of experience with some agencies claiming accreditational jurisdiction that have applied distinctly rigid and not always rational criteria for acceptability, these institutional presidents have very real concern lest their freedom to experiment, to develop their institution in terms of its particular function and its ideals, be unreasonably and seriously curtailed. They believe that the institution itself holds the real responsibility for pioneering and for setting patterns in the educational field. They believe that the educational institutions particularly have the responsibility for developing new ideas, experimenting in unconventional directions, and in encouraging today's radical innovations, some of which may be recognized in years to come as major advances in our intellectual growth. They believe that any authority for institutional standards assumed on the part of outside agencies without the corresponding responsibility for achieving sound results is unwarranted and unsound authority.

I doubt that any of us can disagree very seriously with these rather fundamental ideas. Yet certain implications of the concept of *noblesse oblige* may be involved in their attitude and responsibility toward accreditation activity.

On the other hand, government is recognized as properly responsible for protecting the public against incompetent professional practitioners, or those who fraudulently assert themselves to be such practitioners. Thus registration of members of professions appears to be an inevitable fact. Assurance of adequate minimum educational experience as a prerequisite preparation or component of preparation for professional practice is important. Thus it appears inevitable that some kind of safeguard against unjustified recognition of inferior educational opportunities offered to students be achieved. The real problem therefore lies in achieving means of drawing that fine line between assurance of adequate standards on the one hand, and imposing unhealthy, and in the long term, unsound educational restraints on our vigorous and experimentally-minded institutions on the other.

These are some of the problems before those who accept responsibility on behalf of their professions for accreditation activity. They share these problems with governmental registration bodies on the one hand, and with educational institution administrators on the other. The evolution of a sound and wise answer to this rather complex situation with its demands and with its hazards offers opportunity for all the wisdom and statesmanship that we as engineering educators can provide.

College Notes

The appointment of Harold Ellithorn as Head of the **University of Notre Dame's** Department of Electrical Engineering was announced recently. He will replace John A. Northcott who resigned for reasons of health. Professor Ellithorn is a specialist in network theory.

The union of industry and the **University of Michigan's** College of Engineering is anticipated under the terms of a broad program being launched by the University. Known as the Industrial Program, the plan is designed to open direct channels of communication between the College and industry, and to bring about greater understanding and cooperation between the two.

Under the program, subscribing industries will receive information on the College's latest engineering and scientific advances at nominal cost, and University and industrial experts will meet periodically to review their mutual fields of interest.

New laboratories dedicated to the fundamental research which will exploit the vast peacetime potential of electronic and nuclear science will be built as the **Massachusetts Institute of Technology's** memorial to the Institute's late chairman, Karl Taylor Compton. James R. Killian, Jr., President of M.I.T., speaking at an Institute-wide convocation in commemoration of Dr. Compton, announced plans for building the Karl Taylor Compton Laboratories for Nuclear Science and Electronics.

Engineering Ethics—From the Viewpoint of Industry *

By GERRY E. MORSE

Vice President in charge of Industrial Relations, Minneapolis-Honeywell Regulator Company

Engineering ethics, from the viewpoint of industry, are of steadily increasing importance. The gain is in proportion to the growth in the depth and complexity of the technology of industrial processes, products, and product application.

The development of modern industrial technology, which has produced a steady rise in living standards through more and better things for more people, has also brought along with it a management problem that almost did not exist 40 or 50 years ago. This is engineering in industry.

A half century ago the invention, development and application of new products were largely in the hands of the lone inventor and the gadgeteer. Edison, Eastman and Ford are examples that come readily to mind. Similarly, Minneapolis-Honeywell owes its start to a relatively simple mechanical damper control invented by a tinkerer named Al Butz. Butz' idea was to have a temperature sensing device in the house that would open and close the dampers on the furnace in the basement, and thus eliminate a lot of running up and down the cellar stairs. So, on a rule of thumb, trial and error basis, he applied in rather crude fashion some relatively simple scientific principles to achieve this end.

Today in our Company, which we characterize as "First in Controls," about one in every 10 employees is in engineering or research activities. Our development along this line is not unique. Its parallel, to a greater or lesser degree, is to be found in most manufacturing companies. When we consider that today roughly two-thirds of our total of approximately 400,000 engineers are employed in industry, it is apparent how rapidly this aspect of industry has developed.

The modern industrial product is in many cases a highly complex device in itself, and almost without exception is produced by a highly complicated process. The design of the product and the means for producing it are no longer alone in the hands of the gadgeteer or even of the practical manufacturing man. A modern industrial organization depends on highly talented and trained professional engineers and scientists for the technical aspects of its work. It must employ them in relatively large numbers. Without them it could not exist.

The engineer in modern industry works in areas that are close to the very core of management decision. The engineer is responsible for the technical development of the products, processes and customer applications on which the success of the business depends. His ability to create, test, control, and improve the product, and the soundness and practicality of his professional judgments are important elements in determining the fortunes of the organization. Because the organization is dependent upon him, and because he is entrusted with a responsibility that others in it can not do

* Presented at the Annual Meeting of ASEE, Relations With Industry Division, University of Illinois, June 15, 1954.

or often can not even check, it is essential that the engineer be clearly aware of the ethical requirements of his profession.

While questions of ethics may arise in any interpersonal relationship where one puts himself or his fortunes in the hands of another, they tend to be most serious when professional service is involved. Two basic elements in the professional relationship are responsible. First, a profession is distinguished from a skill or a craft, no matter of how high an order the latter may be, by the degree of subjectivity involved. The professional goes beyond a routine, a formula, or an established habit pattern. He is sensitive to the uniqueness of each situation. His results are not predictable in terms of time or effort but flow from his individual and independent discretion and judgment. He alone knows with what understanding, competency, and likelihood of success he approaches the assignment. Ethically, he has the responsibility to advise his client or employer if other help is required. Parallels are observable in other professions. For example, the clergyman may advise the help of the doctor or the psychiatrist, the physician may advise calling in a specialist, or the jurist may advise his own disqualification from a case.

Second, the professional is characterized by the specialization of his aptitude, education, and experience. He knows and can do what the non-professional does not know and can not do. In professional matters the non-professional is almost completely and blindly dependent on him. Ethically, therefore, he has the responsibility to protect his client or employer and the client's or employer's interest. Parallels are observable in other professions. For example, the teacher may advise against further study because lack of aptitude makes it a waste of time, effort and money, or the lawyer may advise dropping a suit because further prosecution of it would simply drain away his client's or employer's funds.

The True Professional Does Not Trade Dishonestly Upon Ignorance

Both of these aspects of the ethics of engineering, or of any profession, may be summarized in the concept that no intentional, and insofar as possible no unintentional, unfair advantage is to be taken of the client, employer or user. Or, to say it another way, the true professional does not trade dishonestly upon the ignorance of others.

Ethics is largely an individual matter. The ethics of an organization or of a group tends to be simply an integration of the ethics of its members. It is from this point of view that we approach the question of ethical practice in the engineering profession as it relates to collective bargaining. It is not reasonable to say that membership in a collective bargaining organization in itself alone, constitutes a breach of ethics for the individual engineer. Nor is it sound to make a charge of unethical practice on the part of engineering unions except in specific cases where such lack of integrity on their part has actually taken place. Experience to date seems to support the hope that we can have enough faith in engineers as individuals to expect that unethical practice will be found to be one of the least important faults of engineering unions. There are aspects of the problem, nevertheless, which do warrant our study and concern.

Let us review the historical background of the collective bargaining movement among engineers. After the passage of the Wagner Act in 1935, some engineers and other professional employees were, against their will, being forced into labor organizations composed predominately of non-professional employees. Theoretically, engineers were free to form collective bargaining organizations of their own, or free to deal as individuals. In cold reality they were at a disadvantage because of the NLRB practice of including them in larger units. In such cases, because of their relatively smaller numbers compared with other non-supervisory

office or factory employees, they found themselves outvoted in representation elections and included in general factory or office bargaining units. In 1937, ASCE formed a "Committee on Unionization" to study the problem. Despite ridicule and scorn, ASCE pressed the study and by 1944 had developed a plan under which engineers seeking to organize could receive guidance. Then, in 1947, through the combined efforts of ASCE and the other constituent societies of the Engineers Joint Council, the so-called "professional employee" provisions were written into the Labor-Management Relations Act, commonly referred to as Taft-Hartley. The Act, as you know, guarantees professional employees the right to decide whether they will form a labor organization of their own, be included with a non-professional labor organization, or deal with their employer on an individual basis. It was during this hectic period that most of the present day engineering collective bargaining units were established.

Although we cannot know for certain what was in the minds of those of the engineering profession who were instrumental in creating and developing collective bargaining organizations of professional employees, most of them said on the one hand they were trying to prevent being included in units with non-professionals and on the other hand that they foresaw the development of organizations of professional employees for collective bargaining purposes which would bee different in character from the typical labor union. They made the fundamental error of assuming that a collective bargaining relationship between a group of professional employees and management could be very cordial and dignified and that problems would be solved forthrightly without resort to the exercise of power or the strategical and tactical maneuvering of the typical collective bargaining situation. Nor is it likely that they foresaw—there is no reason to suppose they had the necessary understanding or experience to do so—that an engineering union or any organization that engages in collective bargaining must inevitably adopt the typical tactics, practices, and characteristics of the trade union.

My experience in collective bargaining convinces me that it is inevitable. Any organization formed for the purpose of collective bargaining, because of the very nature of the demands of its membership upon it and their reaction to its accomplishments on their behalf will sooner or later be forced to resort to the traditional practices of the typical labor union. There is a clearly observable trend by the engineering collective bargaining organizations of movement in this direction. Those of you who have been following the published reports are aware of it. For example, you see it in the behavior of the collective bargaining organizations representing the engineers of some of the West Coast airplane manufacturers, of some of the electronics companies in the New York city area, and of Minneapolis-Honeywell here in the Midwest.

You see extravagant demands, heated and protracted negotiations, costly strikes, the creation of a national organization, the Engineers and Scientists of America, to extend collective action beyond the scope of the local unit, and action in concert with unions that represent non-professionals.

Observable Trends

Some other observable trends within engineering collective bargaining organizations deserve attention. First, the average or better than average engineers, or the ones who really understand the individual and professional nature of engineering work seem to become apathetic toward collective bargaining. They seem to sense on the one hand the inevitable danger of the tendency of group action to result in "leveling down" and find they can get better job satisfaction, better advancement, and better pay on the basis of their own individual effort than on a group basis. They lose interest in the

collective bargaining approach and so do not furnish the stability and leadership qualities to the group that they might if they participated more actively. Second, those of the collective bargaining organizations that have heterogeneous memberships composed of engineers and non-professionals are tending to develop an internal divergence of views and aims. The very fact that the work of the non-professionals lends itself more readily to standardization and the members of the group to more easy interchange makes collective action of interest to them and a more satisfactory experience. Thus, even if they are a minority, their views and power tend to become dominant in the collective bargaining activity. Finally, there is the noticeable restriction on communication between management and the engineer where a collective bargaining representative is selected by the engineers to replace them in dealing with their employer on wages, hours, and other conditions of employment.

For all of these reasons there is a very serious question in my mind as to the compatibility of collective bargaining and engineering. There is, I believe, a fundamental conflict between the practices inherent in collective bargaining and the kind of unregimented atmosphere that must prevail in an engineering organization if it is to function professionally and accomplish the results for which it is employed. An employer does not hire an engineer in the same sense he hires a janitor, an assembly man, a truck driver, or a tool and die maker. He selects the engineer as a professional, just as he would select his own doctor or lawyer. He is interested in more than technical competence, education, and previous experience. Because he is putting his fortunes into the hands of the engineer insofar as he must rely with complete confidence on the engineer's professional opinions and actions, he is intensely interested in the engineer as a person. Just as a clergyman can not effectively serve his parishioners unless there is a freedom of communication and sympathetic "ease" between them, or a teacher cannot effectively lead his students to learning unless there is a mutual respect, confidence, and interchange of ideas, so the engineer can not fill his place in the industrial organization unless he has the right personal "fit." At Minneapolis-Honeywell, for example, we find it necessary to interview about 100 engineers to find 10 whom we feel we should consider for employment. Of the 10 on whom we spend the time, effort and money for testing, for multiple interviews, and for visits to our plants, we make actual offers to about 6. Of the 6, only 2 or 3 accept and are hired. A similar, although less easily observable selection, takes place in our assignments of work and position advancements of engineers.

A tendency to obscure the professional and highly individual character of engineering employment has resulted from the popularization in recent years of the idea of team-work within the industrial unit. While the engineer is on one hand a member of the team together with managerial, financial, manufacturing, sales, and all the other employee groups that make up the typical company, he remains, on the other, essentially an individual insofar as his professional responsibility is concerned. Even in a department of hundreds of engineers the fundamental reason for their employment and the requirements of their work remain unchanged. Professional problems are solvable only by individuals. Others may help to stimulate the individual, different approaches may be tried by different individuals simultaneously, sub-professionals or non-professionals may aid through supplying related, supplemental, or directed services, but in the absence of successful individual effort and accomplishment, the term, or committee, or organization will fail. It is at this point that the incompatibility of professionalism and collective bargaining stands out sharply.

Impact Upon Engineers

Those of us who have had experience in collective bargaining with engineers have seen the impact that it has upon them. Collective bargaining is a process of give-and-take, of argument, of compromise. In other words, it is collective and it is bargaining. Engineers are not conditioned by temperament or training to feel comfortable in the pulling and hauling of the collective bargaining process. They tend to seek what they believe to be the right answer to the problems raised, not recognizing that some are purely political, growing out of the needs of a collective action and that others are simply part of the strategy and tactics, the horse-trading, of the bargaining technique. Engineers, tending to approach such problems along the route of the scientific method, are more often than not, bewildered when that does not work, and tend to find it a very frustrating experience.

In view of this how can we account for the fact that some 13 or 14 different labor organizations currently represent engineering employees and for the fact that unionization is today one of the "hottest" subjects under discussion by engineers. Primarily I believe it is one of the manifestations of the awakening of engineers to the fact that engineering is a profession and that its professional status should be raised and made better known to the public. Dissatisfied with the failure to date of any overall unifying organization, some engineers have turned to unionization as a possible answer. They apparently make the error of believing that the overall organizations in the medical and legal professions are collective bargaining organizations.

Furthermore, the demands which the engineering collective bargaining organizations have made in recent years seem to be based much more on the economic position of the engineer in society than upon dissatisfaction with local conditions. Therefore, we may look upon the question of engineering unions as a national problem rather than a local one. For the moment, at least, engineers as a group seem over-whelmingly concerned with their level of pay. Feeling that the unions and union practices have tended to raise the pay levels of their members, some engineers have turned to unionization as an apparently quick and easy way to get their own pay raised. I believe the engineers who, for whatever reason, chose this approach make a serious mistake and that organization for collective bargaining is definitely not the answer to the engineer's problems. First of all, scientific and engineering accomplishment thrives best in a free and unregimented atmosphere; second, the traditional practices of trade unions, while inevitable, are impracticable in an engineering organization, and third, the engineer by nature and training finds the practices of collective bargaining unsatisfactory and unacceptable.

Courses of Action

Therefore, we need to consider what courses of action we might take in dealing with this problem.

First, the schools and colleges. They must somehow instill in the young engineer the conviction that he is a professional and that he and his profession will progress only in proportion to the exercise of his own abilities and efforts. He must understand that his own inner resources will take him most rapidly and profitably along the road he wants to go. I am not so sure that as a layman I know how this can be accomplished, but if engineering is to become a highly accepted profession, those who practice it must learn the meaning and ethical responsibilities of professionalism.

Furthermore, the schools and colleges may defeat their very purpose when they advise or condone the better men refusing employment with a company solely because its engineers are in a collective bargaining unit. It is only by having

the better engineers meet this challenge and lend their influence in such groups that the question can be satisfactorily resolved. To isolate them may result in a permanent division of engineers into two opposing camps.

Second, the Technical Societies. The technical societies must look beneath the surface of the collective bargaining question in order to understand it and meet it. This will take patience and understanding. The problem can be evaluated and solved only in a calm and tolerant atmosphere. It is a problem already overcharged with emotionalism. The societies do need to be more vigorous in finding the key to some unification or integration in professional affairs. On the other hand, to try to meet the problem of unionization by becoming collective bargaining agencies themselves would be fatal. They would inevitably then find themselves moving in the direction of the typical labor union behavior and practices.

Third, industry. Industry has a serious challenge to understand and practice its part in the professional relationships with its engineers. Under the law, if its engineers elect to bargain collectively it must do so in good faith. On the other hand, it must at the same time make certain that the collective bargaining does not destroy, any more than can possibly be avoided, the maintenance of that freedom of individual accomplishment and of intercommunication that is essential to the attainment of the best professional results.

Finally, the engineer himself. Whether or not engineering advances as a profession or whether collective bargaining or the individual relationship is to be characteristic of the engineer in industry rests almost entirely with the individual engineer himself. The most any of the rest of us can do is to encourage him to take a sincere interest in this important subject, to create an atmosphere conducive to his proper consideration of it and to supply him as completely and objectively as we can with the views, experience, and data we may have on it. Engineering ethics, from the viewpoint of industry, will rise or fall on the decisions of the engineer himself.

The Growth of Graduate Study in Engineering*

By HENRY H. ARMSBY

Chief for Engineering Education, Department of Health, Education & Welfare

This paper is one of three to be presented by a panel formed to explore the future role of graduate study in engineering and to furnish some background material for a comprehensive study of graduate engineering education, somewhat comparable to the study which has been underway for the past two years by the ASEE Committee on Evaluation of Engineering Education. The special function of this paper is to present a few statistics and estimates, gathered from various sources, which outline the growth of graduate engineering study up to the preesnt time, leaving to other members of the panel any attempts to forecast the future.

To a mathematician these statistics will probably leave something to be desired, since the agreement among different sets of statistics is not perfect, for many reasons. Perhaps the chief reason for the differences is the fact that our definitions of "engineer" and "scientist" are not entirely satisfactory. In this respect, the engineers are better off than the scientists, since there is a little greater agreement as to who is an engineer than there is as to who is a scientist. There is also more information available about the engineering profession than there is about natural scientists. Only within the last few years has an attempt been made to gather accurate statistics on these groups.

However, there is no need for great concern over the absolute accuracy of the figures. The lack of agreement between different sources is not sufficiently large to invalidate general comparisons, and the overall picture of the situation with respect to graduate study in engineering is reasonably accurate.

Numbers of Engineers and Scientists

A few general figures may serve to set the stage for more detailed ones. There is general agreement that the total number of engineers at the present time is approximately a half million, which is about 12 times the number of engineers we had in 1900 and about twice the number we had in 1940. Something like 80% of these are college graduates, and the proportion is steadily increasing. Probably the great bulk of replacements and of new additions will come from the engineering colleges. The number of scientists is generally considered to be somewhat less than half the number of engineers. This number has also approximately doubled since 1940.

The National Science Foundation Report

A report prepared in January 1954 by the National Science Foundation for the Science Advisory Committee of the Office of Defense Mobilization shows that the population of the United States increased from 39.8 million in 1870 to 151.4 million in 1950, an increase of 280 per cent. During the same period the number of professional, technical, and

* Paper presented before the Graduate Studies Division at the Annual Meeting of the American Society for Engineering Education, June 16, 1954.

kindred workers increased from 0.4 million to 5.0 million, an increase of 1150%; and those employed in science and technology increased from 12 thousand to 1019 thousand, an increase of 750%. From 1930 to 1953 the population increased 28%, the number of engineers 133%, and the number of scientists 335%. In this report the term "Scientists and Engineers" includes those with baccalaureate or higher degrees, or their equivalent in professional experience, who are employed in the recognized branches of the natural sciences, the engineering sciences, and mathematics.

The same report states that from 1912 to 1951, inclusive, a total of 46,711 doctorates were conferred in science and engineering, of which 47% were in the physical sciences, 42% in the biological sciences, 5% in the earth sciences, and 6% in the engineering sciences.

The American Council on Education Report

All levels of education, secondary, college, and graduate, have grown rapidly since 1900, with the graduate level showing the most rapid growth. A report published by the American Council on Education in 1951 entitled "The Production of Doctorates in the Sciences, 1936 to 1948" contains a large amount of valuable data. In this report the term "science" is used to include the physical sciences, the biological sciences, the earth sciences, and engineering, and a "scientist" is defined as a person having a doctor's degree in one of these fields.

The authors of this study present evidence which suggests that the three levels in education have taken hold in America in waves about thirty years apart. Enrollment in secondary education grew from 4% to 32% of the age stream (14 through 17) during five decades starting with 1870. This agrees almost exactly decade by decade with the growth in higher education enrollment from 4% to 29% of its age stream (18 through 21) for five decades starting with 1900. Relating enrollment to its age stream has the effect of holding the population constant, and shows how much faster the enrollment has grown than has the population in the age group under consideration. Thus the figures quoted above mean that from 1900 to 1950 college enrollment grew 7 times as fast as the number of persons of college age. This is about what happened to high school enrollment 30 years earlier, when it grew 8 times as fast as its age group. There is some evidence that graduate enrollment has started on a similar expansion.

The study shows that between 1890 and 1950 enrollment in secondary education grew to 36 times its original number; in all higher education to 17 times; and in graduate schools to 100 times. Factors for completion of various levels of education are; high school graduation 52 times, bachelor's and first professional degrees 28 times, master's and second professional degrees 58 times, doctor's degrees (all fields) 50 times, doctor's degrees (science) 71 times.

As fractions of the age stream the growth factors are as follows; high school graduation 20 times, bachelor's degrees (excluding veterans) 10 times, doctor's degrees (all fields) 24 times, doctor's degrees (science) 33 times.

The authors of the study state that "the principle is clear that, within limits, social factors are stronger than variations in the actual number of persons in the age stream. Whatever the 1960 college enrollment turns out to be will depend primarily on social factors, the demand for educated persons, and the facilities for obtaining an education. The high school data make it perfectly clear that amazing growth can be achieved over and above population change."

Of the doctorates earned during the period covered in detail by this report (1936–1948) 5% were earned in engineering, 32% in chemistry, 9% in physics, 5% in mathematics, and 4% in the earth sciences. Of those who had earned doc-

TABLE 1

GRADUATE DEGREES IN U. S. COLLEGES, DISTRIBUTION BY FIELD OF SPECIALIZATION, 1929–30 TO 1952–53

Field of specialization (1)	1929–30 (2)	1939–40 (3)	1949–50 (4)	1950–51 (5)	1951–52 (6)	1952–53 (7)
Engineering						
Number	812	1,460	4,913	5,345	4,620	4,084
Per cent of total	(4.7)	(4.9)	(7.6)	(7.3)	(6.5)	(5.9)
Physical Sciences						
Number			4,682	4,881	4,774	4,425
Per cent of total			(7.2)	(6.7)	(6.7)	(6.4)
Mathematics						
Number			1,134	1,293	1,008	918
Per cent of total			(1.7)	(1.8)	(1.4)	(1.3)
Healing Arts and Med. Science						
Number	104	547	1,683	1,722	1,999	1,982
Per cent of total	(0.6)	(1.8)	(2.6)	(2.4)	(2.8)	(2.9)
Biological Sciences						
Number			2,796	3,135	3,071	2,857
Per cent of total			(4.3)	(4.3)	(4.3)	(4.1)
Agriculture and Forestry						
Number	405	822	1,873	1,947	2,020	1,943
Per cent of total	(2.3)	(2.7)	(2.9)	(2.7)	(2.8)	(2.8)
Social Sciences						
Number			11,932	12,127	8,838	11,047
Per cent of total			(18.4)	(16.8)	(12.4)	(15.9)
Education						
Number	1,486	9,957	21,062	25,326	27,528	28,184
Per cent of total	(8.6)	(33.3)	(32.6)	(35.0)	(38.7)	(40.6)
All Others						
Number	14,452	17,235	14,777	16,694	17,296	13,892
Per cent of total	(83.8)	(57.3)	(22.7)	(23.0)	(24.4)	(20.1)
Total						
Number	17,259	30,021	64,852	72,470	71,154	69,332
Per cent of total	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Exhibit						
Eng'g, Phys. Sci., and Math.						
Number			10,729	11,519	10,402	9,427
Per cent of total			(16.5)	(15.8)	(14.6)	(13.6)
Ph.D. Degrees, All Fields						
Number	2,216	3,290	6.633	7,338	7,683	8,309
Per cent of total	(12.9)	(10.9)	(10.2)	(10.1)	(10.8)	(12.0)

torates in engineering about 64% were engaged in engineering as such. Corresponding figures for the other fields are; Chemistry 98%, Physics 96%, Mathematics 100%, and Earth Sciences 116%. The last figure means that at least 16% of the earth scientists earned their doctorates in some other field.

Developments since 1950

Most of the statistics quoted thus far show developments up to about the year 1950. It is somewhat unfortunate that many of the statistical studies concerning scientific and professional manpower stop with this year, since for a good many indices this year marked the all time high point, as is evident in the three tables which form a part of this paper. The data in these tables for the two decennial years 1929–30 and 1939–40 are drawn in part from records of the U. S. Office of Education, and in part from the previously mentioned report of the American Council on Education. Those for 1949–50 and subsequent years are taken from the Office of Education annual studies of earned degrees in U. S. Colleges. The breakdown by fields is less complete for the years 1929–30 and 1939–40 than for 1949–50 and subsequent years, but the figures which are shown for the earlier years are believed to be comparable to those for the later years.

Table 1 shows the numbers of graduate degrees granted in each of eight fields since the year 1949–50, and in four of these fields for the years 1939–40 and 1929–30. In each cell the first figure is the number of degrees granted, and the second figure (in parentheses) is this number converted to a percentage of the total number of graduate degrees conferred during the academic year. It will be noted that engineering degrees constituted a rising percentage of the total until 1949–50, but that this percentage has been dropping ever since. Data for the physical sciences and for mathematics are not available for earlier years, but since 1949–50 both percentages have been dropping. The percentage in social sciences declined from 1949–50 until 1951–52, rose again last year, but has not yet returned to its 1949–50 level. The

TABLE 2

GRADUATE DEGREES IN U. S. COLLEGES, AS PERCENTAGES OF 1949–50 DEGREES IN EACH FIELD, 1929–30 TO 1952–53

Field of specialization (1)	1929–30 (2)	1939–40 (3)	1949–50 (4)	1950–51 (5)	1951–52 (6)	1952–53 (7)
Engineering	16	30	100	109	94	83
Physical Sciences			100	104	102	94
Mathematics			100	114	89	81
Healing Arts and Med. Science	6	32	100	102	119	118
Biological Sciences			100	112	110	102
Agriculture and Forestry	22	44	100	104	108	104
Social Sciences			100	101	74	92
Education	7	47	100	120	131	134
All Fields	27	46	100	112	110	107
Exhibit						
Eng'g, Phys. Sci., and Math.			100	107	97	88
Ph.D. Degrees, All Fields	33	49	100	111	116	125

TABLE 3

EDUCATIONAL INDICES
AS PERCENTAGES OF 1949–50 INDICES,
1929–30 TO 1953–54

Index (1)	1929–30 (2)	1939–40 (3)	1949–50 (4)	1950–51 (5)	1951–52 (6)	1952–53 (7)	1953–54 (8)
Enrollments							
All College	45	61	100	93	86	88	92
Undergrad. Eng'g		56	100	87	79	84	92
Graduate Eng'g		31	100	105	110	115	122
Degrees							
All B.S. and 1st Prof'l	28	43	100	89	76	70	
Male B.S. and 1st Prof'l	22	33	100	85	69	61	
Eng'g B.S.	14	24	100	79	58	46	36*
All Graduate Degrees	27	46	100	112	110	107	
Engineering Graduate Degrees	16	30	100	109	94	83	
Phys. Sci. and Math. Graduate Degrees			100	106	99	92	
All M.S. Degrees	26	46	100	112	109	105	
Engr. M.S. Degrees			100	107	91	79	
All Ph.D. Degrees	33	49	100	111	116	125	
Eng'g Ph.D. Degrees			100	125	127	124	

* Estimated.

percentage of degrees in healing arts and medical science shows a slight increase for the three-year period; those in biological science a slight decrease. Graduate degrees in education have shown an astonishing increase in their percentage of the total, and for 1952–53 constitute more than 40 per cent of the total. This is undoubtedly due to the raising of teacher certification standards in various states and localities, and to the nearly universal requirement of graduate degrees as a qualification for educational administrative positions. Perhaps there is a suggestion here for the engineers.

In Table 2 the figures shown in Table 1 are converted for each of the 8 fields into percentages of the number of advanced degrees granted in that particular field for the year 1949–50. The figures, therefore, represent a measure of the relative rates of change of graduate education in the different fields. They show for instance that in engineering the degrees granted in 1949–50 were about 6 times as many as in 1929–30, while in 1952–53 they are only 83% as numerous as they were in 1949–50, and about 5 times as many as in 1929–30. In education the 1949–50 output was about 14 times that in 1929–30, and the 1952–53 output was nearly twenty times. For the healing arts and medicine, the 1949–50 output represented sixteen times that of 1929–30, while the 1952–53 output was almost twenty times. Engineering, mathematics, and physical sciences have consistently lost ground since their peak year of 1950–51, and the biological sciences to a lesser extent, whereas the healing arts and education have consistently gained ground.

Table 3 contains similar comparisons, using the 1949–50 figure as 100%, for a number of different indices, grouped for ready comparison. Enrollment in-

dices are extended to the year 1953–54, others only through 1952–53. The bachelor's degree in engineering shows the largest percentage drop of any of the indices. However, it is encouraging to remember that this year's graduating class will mark the low point, since engineering freshmen have been increasing in number consistently since the fall of 1950, and for this year are 176% of the 1950 class. They should produce, according to past performance, about 34,000 graduates in 1957, which is 65% of the number produced in 1949–50.

The bright spot for engineers in Table 3 is the fact that the number of Ph.D. degrees conferred in engineering has shown a steady climb since 1949–50, as has the total number of Ph.D.'s conferred. The engineering Ph.D.'s exhibited a slightly greater climb during the first two years of this period, but dropped off a little last year. However, the enrollment for candidates for the Ph.D. in engineering has increased each year since 1949–50, so that the index for this year may perhaps be larger than that for 1952–53.

Effects of Selective Service Policies

The number of graduate degrees in engineering and other fields which will be granted this year and in the future will depend to a considerable degree upon the policies of Selective Service with respect to the deferment of graduate students. The *Engineering Manpower Commission Newsletter* No. 58 (dated May 11, 1954) states that "For the year ending April 30th, Selective Service has interrupted the advanced graduate training of approximately 250 students per month, and has taken another 300 per month (average) from those who received bachelor's degrees and who would normally have entered graduate schools for higher degrees in science and engineering."

The Commission also points out that there has been a steady decline in the number of occupational deferments, averaging 900 per month during the last three months for which figures are available, and says "With draft quotas at 18,000 per month, this means that Selective Service is meeting 8% of the requirement from a group that comprises a critical 1% of the labor force."

Basic Federal Policies

Such a situation, in view of the current shortage of engineers and scientists and the probability that the shortage will continue for a good many years to come, points up the need for a realistic, practical, and democratic National policy which will avoid mandatory controls over the civilian population, but which will enable the nation to achieve the optimum development and use of its most important asset, its human resources.

The basis for such a policy was laid down by President Truman in his "National Manpower Mobilization Policy" in January 1951, and was later amplified by the Office of Defense Mobilization in September 1952 in its Defense Manpower Policy No. 8 entitled "Training and Utilization of Scientific and Professional Manpower."

Both these documents stress emphatically the need of the Nation for scientists and engineers, and both are based on the fundamental principle that each individual should be expected to serve in the capacity in which he can contribute most effectively to the total mobilization program.

The Office of Defense Mobilization's Committee on Specialized Personnel has recently prepared a set of recommendations concerning occupational and student deferment policies. The committee calls attention to the Report of the Committee on Manpower Resources for National Security (the "Appley Committee") which stressed the fact that "in the event of an emergency, our resources of highly trained manpower will probably be the ultimate limiting factor in our capacity for full mobilization."

The committee's report indicates its belief that "present occupational deferment practices are not contributing fully to the object of maximizing the technological strength of the nation" and that "the induction of graduate students in science and engineering has significantly reduced our potential of highly trained scientists and engineers," although the undergraduate student deferment program has been quite satisfactory. The committee recommends a general review and revision of occupational and student deferment policies, which they state should be related to long term needs as well as immediate needs, and should be based at least in part on *prospective use* of professional manpower rather than merely on *present occupation*. The committee recommends a continuation of the present criteria with respect to undergraduate student deferments, but with respect to graduate students, it suggests the following;

"(1) When a student has been deferred by his draft board during his undergraduate years, if he is a candidate for an advanced degree his case should be reviewed immediately upon graduation. If he is among the few who are qualified and accepted for graduate study, consideration should be given to extending his deferment.

"(2) If deferment is granted for entering upon graduate study, it should be continued if the student is making satisfactory progress which, if continued, would result in his obtaining the Master's degree (or equivalent) within two years. At the time of this degree, the case may again be reviewed.

"(3) If deferment is granted beyond the Master's degree (or equivalent), it should be continued if the student is making satisfactory progress which, if continued, would result in his obtaining the Doctor's degree within three years."

The favorable reception accorded by the President to the Appley Committee recommendations for a reorganization of the military reserve, the recommendations of the ODM Committee on Specialized Personnel, and the establishment by the Selective Service System of a few experimental committees to advise local and State boards with respect to the deferment of specialized personnel, give some evidence that a realistic National policy concerning the utilization of scientific and professional manpower is slowly evolving. (Editorial Note: These recommendations have since been adopted in essence by the ODM Manpower Policy Committee.)

Mid-Winter Meeting of Engineering Drawing Division

Time: January 27, 28, 29, 1955.

Place: University of Tennessee, Knoxville, Tennessee.

A three day session of technical programs and inspection trips which will include technical papers and panel discussions by teachers of engineering drawing and men from industry. Inspection trips will include Oak Ridge National Laboratories and Great Smoky Mountain National Park. Detailed programs will be mailed to members of the Engineering Drawing Division.

What Is and What Will Continue to be the Supply of People Qualified to Do Graduate Work in Engineering?*

By C. O. HARRIS

Head, Applied Mechanics, Michigan State College

Graduates of Recent Years

The supply of people qualified to do graduate work in engineering is practically limited to those who have graduated in an engineering curriculum and have shown promise of success in continuing their studies. An idea of numbers may be gained from Table 1, which presents the totals of engineering graduates of recent years, from institutions which have at least one curriculum accredited by ECPD.

TABLE 1

ENGINEERING GRADUATES (1)[1]

School year	No. of first degrees
1946–47	18,592
1947–48	27,460
1948–49	41,793
1949–50	48,160
1950–51	37,904
1951–52	27,155
1952–53	21,642
Sum	222,706

Not all of these people are qualified to do graduate work in engineering. Some factor, possibly 25 per cent, must be applied to figures of this type to obtain the number who would be likely to do well in graduate school.

Future Graduates

The future supply of people who are qualified to do graduate work will depend upon the numbers of engineering graduates in the future. Table 2 presents estimates of the numbers projected through 1970.

TABLE 2

COLLEGE GRADUATES IN THE UNITED STATES, PROJECTED TO 1970

School year	First degrees	First degrees, engineering	% engr. deg. of total	8% of total
1939–40	186,500*	11,400*	6.1	—
1949–50	434,000*	48,200*	11.1	—
1950–51	384,000*	37,900*	9.9	—
1951–52	332,000*	27,200*	8.2	—
1952–53	305,000*	21,600*	7.1	—
1959–60	326,000**	—	—	26,100
1964–65	454,000**	—	—	36,300
1969–70	591,000**	—	—	47,400

*Actual.
** Estimates.

The estimates of numbers of first degrees are taken from a paper by Oxtoby, Mugge and Wolfle (2). An interesting figure in the background of these estimates is that the proportion of high school graduates who enter college appears to have stabilized at about 35 per cent. Wolfle (3) states that the percentage of graduates majoring in engineering remained fairly constant from 1900 to

*Presented at the Annual Meeting of ASEE, Graduate Studies Division, University of Illinois, June 16, 1954.

[1] Numbers in parenthesis refer to bibliographical items at the end of the paper.

1950. The three figures in the last column of Table 2 are 8 per cent of the total numbers of first degrees, and represent one estimate of the numbers of engineering graduates. The estimates in Table 2 are based on long-time trends and are subject to deviation, due to such factors as depressions, wars, GI bills, etc. However, it is interesting to note that it may be some time before the numbers of engineering graduates are substantially above those of recent years.

Again, not all of these graduates will be qualified to do graduate work. However, the numbers do indicate the size of the pool from which the engineering graduate students of the future must be drawn.

On whether the percentage of engineering graduates qualified to do graduate work is likely to increase, Dr. Dael Wolfle, Director of the Commission of Human Resources and Advanced Training, says, "A little general information indicates that the caliber of college students has not changed significantly for the past thirty years. . . . One of our own studies adds the additional fact that the relative standing among college graduates of those who specialize in any particular field has not changed since 1920 at The Ohio State University—the one school where we were able to make detailed analyses of this kind."

Effect of Military Service

Many promising students are likely to forego graduate work because of their obligations to military service. Mr. Armsby has discussed Selective Service policies and practices in his paper. In addition to those students who have been, or are likely to be drafted, there are many engineering students who are enrolled in advanced work in the Reserve Officer Training Corps, and who face two years of military service when they graduate. Table 3 shows the percentage of juniors and seniors in engineering who are enrolled in ROTC at Michigan State College, as an example of conditions at one Land Grant college.

TABLE 3

Spring term	% juniors in ROTC	% seniors in ROTC
1952	43	23
1953	30	36
1954	32	35

TABLE 4

UNDERGRADUATE STUDENT CHARGES AT AMERICAN UNIVERSITIES (4)

Type of univ. and number reported on	Av. 1940	Av. 1950	% increase
Private (24)	$330	$504	52.6
Public, resident (25)	103	158	54.0
Public, non-resident (25)	193	349	81.2

Industrial Opportunities for the Graduate

The great demand for engineering graduates has led to such attractive financial offers to graduates that many excellent students who could benefit from graduate work choose to enter industry immediately upon graduation. This fact is well known to all of us, and must be considered as a factor in estimating the future supply of graduate students.

Increase in Student Charges

The increase in the cost of maintaining a student in college is likely to cause many capable students to decide not to attend graduate school. Student charges have increased substantially at American universities, as is shown in Table 4. Tuition for graduate students may not be an important factor, since tuition is waived for so many graduate students, but the payment of high tuition rates and high prices for board and room during four years of undergraduate school may have placed such a financial burden on a young man and his family that he feels a need to start earning as soon as possible.

Those Who Don't Go to College

There is an abundance of evidence to show that there are many capable young men who do not attend college, often for economic reasons. The President's Commission on Higher Education (5) cites a University of Minnesota study in the early 1940's to the effect that for every student in the top 10 per cent of his high school class who goes to college, there is one in the top ten per cent who does not go; for every student in the top 30 per cent who goes to college, there are two who do not go. Also, Millett (4) says that only 60 per cent of the top 2 per cent, in intellectual promise, of the 18 year olds in this country enter college; only 44 per cent of the top 10 per cent enter; and only 40 per cent of the top 25 per cent enter.

Wolfle (3) tells of a study of all the Minnesota high school graduates of 1950, by Ralph Berdie, who found that about half of those who were in the top 10 per cent, but who were not going to college the following year, said that they would go to college if they had the money.

The President's Commission has recommended a broad program of undergraduate scholarships to enable more of the most highly qualified young people of this country to go to college. Any development of this type is certain to add to the number of people who are qualified for graduate study in engineering.

Distribution of Ability

Some information is available on the distribution of ability among graduates in engineering. The figures in Table 5 are test scores converted to the Army General Classification Test Scale. On the AGCT scale, the average person in the total population earns a score of 100. Also, it might be taken as an approximate statement that a score of 110 indicates the minimum level of ability for graduation from college. The average person earning a bachelor's degree scores about 126.

TABLE 5

PERCENTILE SCORES OF ENGINEERING GRADUATES (ON AGCT SCALE) (6)

	Percentile				
	10	25	50	75	90
Graduates	115	122	129	137	145
Graduate Students	118	123	131	139	145
Ph.D.'s	121	131	138	149	153

The meaning of the term *percentile* may be explained by the statement that a person in the 25th percentile scored higher that 24 per cent of those who took the test, but lower than 75 per cent.

Table 5 indicates that there is not a great deal of difference, on the AGCT scale, between engineering graduates and graduate students in engineering. Also, a substantial number of graduate students in engineering score lower that the 50th percentile of engineering graduates. If these people can be successful in graduate work in engineering, it would certainly be of interest to inquire how they were able to rise above their seeming intellectual level and do well enough to impress an engineering faculty as being qualified for graduate work. If there are special motivation factors present in these cases, it would be desirable to discover them so that they might be applied more broadly. It would also be of interest to see how successful such people are in graduate study, and whether they do manage to complete a rigorous program of work.

Whatever the conclusion on this point of distribution of ability, it appears to be a proper subject of inquiry for those interested in the supply of people qualified to do graduate work in engineering.

Summary

It appears that, by 1970, the number of engineering graduates per year will approach the number of the peak year of 1949–50, up to an estimate of 47,000,

and that the percentage who are qualified for graduate work will remain about the same as at present. However, such factors as military service, high industrial salaries and increases in student charges may cause many excellent students to forego graduate work.

There seems to be some hope for increasing the number of qualified graduate students in a program of undergraduate scholarships and in a study of distributions of ability.

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College Notes

Polytechnic Institute of Brooklyn, the country's second largest engineering school, will emphasize interpretation of its centennial theme, "Science, Engineering, Research for Human Well-Being," during its centennial year, according to the plans disclosed by President Harry S. Rogers. Chartered in 1854 as the Brookyln Collegiate and Polytechnic Institute, the school admitted its first class of 267 students in September 1855. Today over 6500 students attend its undergraduate and graduate schools in day and evening sessions.

Prof. Frank Kerekes, well-known structural engineer and teacher, has been appointed dean of academics at the **Michigan College of Mining and Technology** by the Board of Control, it was announced by Dr. Grover C. Dillman, president of the college and secretary of the Board.

Kerekes has been on the faculty of Iowa State College since 1920, where he served as professor of civil engineering and assistant dean of engineering.

Formation of an Engineering Council of 24 men to advise and assist in the development of the **University of Pittsburgh** schools of engineering and mines was announced by Chancellor R. H. Fitzgerald and Dean G. R. Fitterer, dean of the schools.

Factors Affecting the Supply of Graduate Students in Engineering*

By D. F. PETERSON, JR.

Professor and Head of Civil Engineering, Colorado A. & M. College

Introduction

My topic for discussion is the question, "What measures are likely to be successful in increasing the supply of graduate students in engineering?" Preliminary thinking about this topic led to the early realization that a comprehensive study arriving at the relative importance of the various factors and predicting the possible quantitative results which might be achieved would be beyond the scope of my individual effort. This paper, therefore, will be limited to simply summarizing some of the more likely factors involved and commenting on some of the more obvious aspects of these. Our chairman has already sounded a call for a comprehensive evaluation of graduate education in engineering, and if this study is made, certainly the topic which has been assigned to me for discussion here today will be developed fully and quantitative answers arrived at.

Separating graduate-student manpower problems from the problems of undergraduate manpower is impossible. Accordingly much of this discussion may, on the surface, appear to be concerned with under-graduate problems. I think, however, the relation to graduate problems will be evident.

Presumably any program which leads to an increase in either the quality or number of high school graduates entering engineering colleges ought also eventually to increase the supply of graduate students in engineering.

Although current studies indicate a large and continuing deficiency of engineers educated at the bachelor's level, I think that economic returns to the members of the profession and benefits to society as a whole might be greater if we concentrate on improving quality more than increasing quantity. A normal and healthy increase in bachelor-engineers, consistent with increasing population and industry, is certainly desirable; but I doubt the wisdom of making every possible effort to "get all the engineering graduates that we possibly can."

The problem we face has been stated many times. Each member of our rapidly multiplying population demands more and better material goods in the face of decreasing natural resources and more complex social, economic and political problems to solve. At the same time we are faced with the prospect of inordinate technological expenditure of men and resources for war machinery to insure national survival. These demands can probably never be fully met. The only hope of meeting the minimum is to substitute more machine power for manpower. This will require increasing the supply and efficiency of brain power. We must increase the number of young people capable of working with their brains and we must utilize these much more effectively than in the past.

In our search for an increased number of graduate students in engineering we

*Paper presented before the Graduate Studies Division at the Annual Meeting of American Society for Engineering Education, June 16, 1954.

must not overlook that the sciences and other intellectual fields also will be under great pressure for more brain power. Any practical answer to our problem must consider these requirements also. *Our efforts in evaluating graduate education in engineering, especially as they relate to manpower problems, ought to be correlated with a general study of these needs for all of the sciences.*

Factors Influencing Graduate Engineering Manpower Supply

Factors which might influence young people to follow graduate study in engineering appear to fall into two broad categories. The first of these appears to consist of factors which are clearly economic in nature. The second is not so clearly strictly economic but involves psychological considerations as well.

Economic Factors

Prospect of increased individual financial return.—The prospect of increased individual financial return is probably the most potent motive that could be introduced to stimulate graduate study. The greater this prospect, the greater would be the expected increase in graduate-study interest. Presently little difference seems to exist in the financial returns to persons with advanced degrees in engineering over those holding bachelor's degrees.

We have assumed that graduate study in engineering is valuable to society. If this is true, why have not supply and demand operated to create a comparable reimbursement? Perhaps the answers may be found partly in the facts (1) that most advanced-degree engineers have been employed in education, which is somewhat protected from the laissez-faire operation of economic law; and (2) that employment by industry of engineers with advanced training is generally relatively recent and that time will be required before persons holding these degrees mature, if they will, into higher paid brackets.

Control of engineering wage scales based on degree held or years of advanced study might be possible. If not by legislation, this could be accomplished by unionization. Pay increases in the education profession often result automatically as the result of no other qualification than possession of an advanced degree. This has stimulated graduate activity in education. Many people feel however that this artificially stimulated endeavor has detracted from the quality of advanced work in the educational field. I certainly do not favor any such drastic measures in engineering.

Increased financial return to better-educated engineers can probably come about only because of proven increased economic worth to industry or to the public of the individual concerned. This may be difficult, because intellectual achievement is sometimes not marketable to society at its true worth. *Without doubt, however, resulting individual financial return to advanced-degree engineers needs to be increased if graduate work in engineering is to be stimulated.*

Meeting the high cost of graduate work to institutions of higher learning.—One important factor affecting the attractiveness of graduate work is doubtless the professional reputation, personal enthusiasm and inspirational quality of graduate teachers and leaders; another is the importance and support available for graduate research programs. Worthwhile graduate work is expensive and universities are faced with a decreasing unit purchasing power in the face of demands for increased mass education at the college level. Many schools have met this problem, to some degree at least, by venturing into contract research. This source of income helps pay professor's salaries, and furnishes assistantships and graduate research projects. Contract research is not without its difficulties, however, as those who are involved are well aware. These programs make additional demands on the already short supply of manpower capable of high-grade graduate leader-

ship. Many research sponsors do not recognize the true costs to the institutions of these activities—staff time, facilities, apparatus, and administrative costs are often not allowed. These costs can be met only by decreased institutional services elsewhere. *More liberal support of sponsored research is needed.*

Industrial contributions to research in colleges has been stimulated in recent years by operation of the excess profit tax and by high corporate income taxes. Under these, each dollar of research effort costs the owners only about 18¢. With the discontinuance of the excess profit tax and the decrease in the corporate income tax, the share per dollar of the cost now becomes about 54¢, thus effectively tripling the cost to the corporation of such research. Perhaps this may not decrease corporate sponsored research as much as the figures indicate, because the corporations will have a larger supply of cash at their disposal. We hope they may recognize the importance of investing continuing large sums in research on our campuses. Perhaps some preferential tax concessions on funds spent this way ought to be considered as a means of stimulating this source of income to the colleges and universities. This public cost could be justified on the basis of the value to the nation of the continuing research effort in colleges.

Contract research grants are helpful, but they can only partly answer the problem. *Graduate schools need more adequate general financing.* This is especially true of the smaller institutions, who find it increasingly difficult to employ and to hold the interest of really well-qualified professors necessary for graduate work. This is true both in engineering and in the supporting sciences. For the publicly-financed institutions some means must be found to make legislatures recognize the importance of investing public funds in graduate activity. Privately-financed institutions have an even more difficult problem of finding adequate financial support.

Increasing the number and value of fellowships and assistantships.—A very important factor in the supply of graduate students must be the availability and monetary value of fellowships and assistantships. Presently research assistantships are relatively easy to obtain. Fellowships are more difficult. Graduate work in engineering would be stimulated if more fellowships were available. The number of fellowships in engineering under the National Science Foundation is helpful but inadequate.

The subsidy to education under the G.I. bill operates essentially as a huge fellowship program. This subsidy has not only directly supported graduate students but has increased the number of graduate students by simply increasing the number of bachelor's degrees. If and when G.I. benefits are discontinued, something will probably have to take their place. *Perhaps the idea of mass subsidy may be replaced by increased public sponsorship of young people of superior ability by the National Science Foundation, and by comparable agencies at the level of state, city and school district.*

Special consideration in regard to military service for talented graduates.—Deferment from their military obligations of talented graduates who wish to pursue further study would be helpful. If our object is to be realized, public policy on this point should probably be liberalized. The problems involved are not simple and extend from current logistic considerations all the way back to our basic concepts of democracy. This aspect of our problem has already had a lot of consideration. It will have to come in for considerably more if we pursue our proposed evaluation of graduate work in engineering.

Availability of graduate courses to young engineers in service.—Doubtless many young engineers who are employed full-time will elect to do graduate work on a part-time basis if such programs are readily available to them. These programs frequently utilize night classes. I have had very little experience with part-

time programs and I will leave discussion of this point to someone else. Co-operation of industry and public agencies is vital to stimulation of programs of this nature. A conference on co-operative education at the graduate level was held at Troy in connection with the 1949 annual meeting of ASEE and the various papers presented have been published as a bulletin of the Graduate Division.

Competition with the sciences for graduate personnel.—All of the sciences are faced with impending manpower shortages. We can accordingly expect that competition for scholars of extraordinary ability will continue. Supply and demand will probably operate fairly well to establish equitable distribution among the various sciences and engineering, and I would not advocate an artificial program to divert manpower from one or another of these professions. *What is needed is a concerted effort on the part of all to encourage talented youngsters to enter science and engineering rather than commercial or other less intellectual fields.*

Psychological Factors

Fortunately not all of the factors which influence young persons to enter a graduate career in engineering are economic. For lack of a better term, I have lumped these factors together and called them psychological factors. There are a great many of these of relatively minor importance, but which, nevertheless, ought to be exploited if we seriously undertake an effort to increase graduate activity. These factors include such items as (1) the opportunity to do creative work of lasting value, (2) the possibility of service to the public, (3) natural scientific curiosity; etc. Stimuli of this kind operate naturally in our favor. Probably ways can be developed to make them more effective.

Another point which would appear to have some influence on a person choosing a profession is the quality of professional status enjoyed by members of that profession. Everyone seems to agree that there is room for improvement in this regard in engineering. A great deal of effort is presently being made by leaders of the engineering profession in an attempt to improve this status. The success they achieve will probably be reflected in some measure in the success of our recruiting efforts.

Engineers, being practical people generally, are apt to mistrust or fail to appreciate persons who have specialized in highly technical subjects at the expense of field experience. This tendency decreases with time as more rigorous technical efforts become increasingly necessary. Perhaps, better general understanding of the place and value of the engineer with advanced education might eventually add to the attractiveness of this kind of career.

There have been some expressions that graduate school administrators do not fully appreciate the desirable features of advanced work in engineering. Most administrators of graduate work are apt to be recruited from the so-called "pure" sciences. I suppose most of the misunderstanding centers around the classical concept that the purpose of graduate work is to conduct research of fundamental nature. *Development of the most useful graduate curricula in engineering ought to improve the attractiveness of these programs. They should be free to develop without being fettered by traditions or by preconceived ideas based on what may be desirable for programs having different objectives.*

I have briefly mentioned a few "psychological" factors. I have little notion of their relative importance. Some of them may prove to be trivial. I have in mind, however, two factors which seem to me to be of primary importance in producing graduate students. These are (1) improvement in pre-college preparation for engineering and the sciences and (2) more inspiring scientific leadership especially in the secondary schools, but also in the undergraduate colleges. I shall discuss these together because it is difficult to separate them.

Improved secondary education in preparation for science and engineering.—Secondary education has suffered criticism because of a tendency toward superficial treatment of science and pre-science work and its neglect of the talented student. I do not wish to enter into a discussion of the justice of this criticism but merely to place the problem before you.

There is certainly evidence that many objectives of our secondary education program are not conducive to the intensive scholarship habits which young adolescents ought to develop if they are to become effective scientists or engineers. There seems to be good evidence also that preparation in the sciences and mathematics is too often omitted altogether or is of inferior quality when it is included. Habits and interests are pretty well moulded in young people by the time they reach 18 or 19 years of age. If the charges laid at secondary education are true, we are not only wasting valuable, formative years; but losing capable people simply because they have developed other interests without ever having a chance to become acquainted with science or engineering. The apathy of young people toward science and mathematics courses in high school probably could be overcome by better and more inspiring leadership in these fields and by reduction of conflicting interests.

The entire problem of secondary education as it relates to preparation for an engineering or scientific career needs a great deal of thought and study. Mass education must be recognized as a powerful force in realizing the American Dream, yet it apparently has the serious and growing deficiency of neglecting the basic education of our potential intellectual leaders. The problems of overcoming these deficiencies and still maintaining the desirable objectives of mass education are not simple. These conflicting objectives and points-of-view have resulted in verbal brickbats being exchanged between scientists and educators recently. *It is time that scientists and engineers sat down with conscientious leaders of secondary education and did something about (1) determining just how serious these alleged shortcomings are and (2) finding some way to improve the situation with as little sacrifice to all desirable objectives as possible. This responsibility falls upon engineers and scientists as much as on high school leaders and teachers. Our assessment of graduate work needs to include this task.*

Intellectual leadership in the college and university.—There is no substitute for the talented, enthusiastic and inspiring teacher and scientist-engineer who stirs the spark of curiosity, skepticism and imagination in his undergraduate students. You all have met these fellows. The only trouble is that we don't meet them often enough. Perhaps some thought ought to be given to where these fellows come from and how we can keep them in contact with our undergraduate student bodies.

Summary

In trying to make an outline of what factors might be exploited to increase the supply of graduate students in engineering I have considered several which stem principally from economic considerations. Other factors, though in part tied to economy, involve principally other motives and for lack of a better term I have taken the risk of calling them "psychological." Without detailed surveys, any statement about the relative importance of these various factors would be speculation. All that seems possible at the present time is to present them for further discussion and possible future evaluation.

In considering these various factors I could not help but be impressed by the fact that generally the factors which might increase graduate enrollment are also those which would contribute to building strong and effective graduate schools.

The Future Role of Graduate Study in Engineering*

What measures are likely to be successful in increasing the supply of qualified graduate students?

By ERNST WEBER

Polytechnic Institute of Brooklyn

The tremendous rate of new developments in all areas of engineering, but particularly in the new fields close to applied science, namely electronics, solid state, nucleonics, shock waves, supersonics, has placed much greater stress upon graduate study in engineering than we have ever known before. It is generally realized that the conventional four year program can be modified in content to lead to professionally effective young engineers, but that the ability to contribute constructively to the progress of the art can not be sufficiently reinforced within that short period. The requirement of advanced basic mathematical and physical disciplines as a background for the study of these newer phases of engineering has by necessity led to graduate programs, at least in the progressive engineering schools, which are fundamental in character and demand high qualifications of analytical ability and real understanding of the generic principles. This we must keep in mind when we discuss the means to increase the supply of graduate students to eventually satisfy the increased need for broad gauge advanced engineers.

No doubt the differential in salary paid for bachelor's and master's candidates by industry has already increased the number of applicants in graduate schools over what it would be without this salary differential. However, this does not by any means guarantee the most desirable caliber of applicants and, indeed, if we examine the situation objectively, we shall find that this experience holds: the ablest students get the best offers in industry and many of them accept; the still good, but not exceptional, students are apt to stay almost in inverse ratio to their ability. It is hard to refuse to train all of them; after all, we have an obligation to use our facilities in the best way we can.

The emphasis of this discussion is, however, on measures which are designed to attract the most qualified students to continue their studies for advanced degree. This has become a rather serious problem because of the general shortage of engineering graduates.

Perhaps we can divide the problem at once into two phases, concerned with the two basic aspects of required cooperation: the senior class man about to graduate, and the junior engineer on the job. In the first case we must exert sufficient persuasion to *keep* the student from *rushing away* from us; in the second case we must persuade industry or government to cooperate with us to *make* the student *come back* to us for graduate work.

Persuasion of the Senior

How shall we impress the best seniors that they can gain professionally by con-

* Presented at the Annual Meeting of ASEE, Graduate Studies Division, University of Illinois, June 16, 1954.

tinuing studies towards advanced degrees and that, in fact, they have an obligation to the nation to cultivate their abilities to the utmost so as to repay in part for the national effort which gave them education? Certainly not by boring them in the upper years while we spend our efforts to train the average! Certainly not by letting our graduate work just be "more of the same thing"! Certainly not by exacting full tuition when industry is offering them the highest salaries!

To be likely successful in this persuasion we must show appreciation of ability in undergraduate years by individualized programs for the outstanding students. True, the ideal is not feasible, the genuine teacher-student relation in the antique sense is too expensive for most institutions, and probably not even justifiable on social grounds. But we can place the excellent students into honors' programs, let them taste some truly graduate work to challenge their ego to the pride of achievement. We can create an atmosphere contagious with the desire to learn more, because we, the teachers, are studying, probing into new fields, keeping in touch with industrial developments which are not yet ready for undergraduate teaching.

Obviously this means a challenge to the undergraduate faculty. It requires probably the existence of a research program of sufficient scope and magnitude, and the existence of a strong graduate program in which the undergraduate faculty to some part at least participates.

But it might also mean a generous fellowship program in order to supply the extra tone of persuasion, rather important in competition for the young graduate. This again might not be feasible within the finances of many institutions so that outside help becomes important. Here is the chance for a most constructive contribution by government agencies, particularly the National Science Foundation! To be sure, slight beginnings have been made in this direction, but by far not of sufficient magnitude to have significant influence upon the plans of graduating classes.

Now, some will argue that all of this discussion pertains to the large professional school and does not take care of the many smaller engineering colleges. Yet, the attitude of the undergraduate faculty in the smaller colleges should not differ in principle from that in the larger colleges, the only difference being that the research program or the graduate school might be quite distant. It is a fact that many outstanding engineers come from small colleges and a definite service to the nation can be rendered by persuading the ablest seniors to continue study in one of the leading graduate schools.

Evening Programs

Desirable as it might be to take the best seniors into graduate schools, we must rationally accept the fact that the majority of them will take positions in industry, excluding for this discussion the various reserve officer training programs. There are two distinct ways in which qualified students can return to graduate study: one is on a part-time basis in evening programs; the other is by enlightened industrial cooperation through partial or full-time graduate fellowships and scholarships. In either case, this type of graduate education can be most successful if undertaken with full realization of the mutual benefits to be derived.

Though individual graduate courses in engineering had been given in the evening at some institutions perhaps since after the first world war, full evening programs for the Master's degrees in the Engineering fields were first offered by Polytechnic Institute of Brooklyn in 1928. During the first ten years of this pioneering effort, much controversy existed as to the relative merits of full-time day and part-time evening study with the usual traditional views burdened by the inertia of faculty councils who apparently abhorred work for credit in the evening. The tremendous success of the program in terms of enrollment, support by industry, and endorsement by other urban institutions has left no doubt that this might

be the most significant contribution to increase the number of qualified graduate students in engineering.

In a special Conference on Cooperative Education at the Graduate Level,[1] arranged by the Division of Graduate Studies of ASEE in Troy, June 22, 1949, the late Dean H. P. Hammond contributed a discussion emphasizing the importance of part-time evening graduate study and referred to a survey of such opportunities for young engineers, made during 1948–1949 by the Engineers' Council for Professional Development (ECPD). This survey[2] showed that of the fifty communities in the United States in which there are sufficient numbers of young engineers to justify the offering of post-graduate courses, and in spite of the proximity of well qualified institutions, only about a dozen realize this opportunity of service. With this report, the Professional Training Committee of ECPD also published a separate pamphlet "The First Five Years of Profesional Development" and suggested in it a six-point program of post-graduate activity which could and should be stimulated by cooperative effort of the employers, the college, and the engineering societies.

As a tangible step in implementation, a cooperative effort was launched by the Training Committee of ECPD in the Cincinnati area. In response to a folder distributed by a local Industry Committee and describing evening graduate courses made available in September 1953 at the University of Cincinnati, a total of 285 qualified graduate students enrolled in nine selected courses![3]

It appears, therefore, that the establishment of strong evening graduate programs has not been as fully exploited as the existing favorable situations might seem to indicate. Partnership with industry as promoted by ECPD should be most helpful in establishing part-time graduate centers and in securing well qualified graduate students, thus serving the nation with the needed advanced professional training.

Obviously, the stress in any such effort must be on strong graduate programs with fundamental courses and with a well selected faculty whose members have earned reputation in their field through contributions to technical programs of professional society meetings or through technical publications or books. It would be a grave mistake to suddenly invite by gentle pressure a faculty only conversant with undergraduate teaching to step out into evening graduate programs. The evening student, having gained his experience in design and test or measurements assignments, is generally more searching with his questions and less ready to accept pretended authority than the day student who steps from his senior year into graduate study!

National Fellowship Program

The cooperation between the engineering school and industry could and should extend to the promotion of full-time graduate study in the exceptional cases where the value of the student to the company warrants the privilege of a fellowship or of limiting leave of absence for the completion of graduate studies. The whole spectrum of possible modes of cooperation at the graduate level has been extensively discussed in the Conference on Cooperative Education at the Graduate Level to which reference has been made previously.

Surely, if industry values formalized advanced training programs, we should expect genuine understanding of the importance of graduate study in engineering. It should be fully realized that in spite of the unquestioned value of com-

[1] See pamphlet "Papers and Discussions, Coperative Education at the Graduate Level," available through Secretary A. E. Bronwell, or through E. Weber at Polytechnic Institute of Brooklyn.

[2] See the 18th Annual Report of ECPD for the year ending September 30, 1950.

[3] See the 21st Annual Report of ECPD for the year ending September 30, 1953, pp. 13–14.

pany course programs, the place for degree programs is in the University and not in industrial establishments; that more can be gained in the long run by generous support of graduate work in Universities than by competitive effort within industry which by economic necessity must have a non-negligible bias in course objectives.

Unfortunately, the fellowship program sponsored by all industrial organizations is very small, indeed, even though it might look large in each individual organization. To be really effective, a fellowship program of much greater proportions would be needed whereby the students, usually married by this time and possibly with family, could take up full-time graduate study with a tolerable loss of income.

Here again is a challenge to government agencies to supply support on a national basis much beyond the limited funds which the National Science Foundation could make available so far. The industrial strength of this nation turned the tide of the second World War. This industrial strength rests upon scientific engineering to a larger extent than might readily be conceded by the production statisticians. To keep the basic contributions of engineering talent at the highest possible levels we must succeed to train the maximum number of our ablest students to their maximum level of attainment!

In the News

The creation of the General Committee on Nuclear Engineering and Science was announced. The new body, organized under the sponsorship of **Engineers Joint Council**, has been established to "meet the pressing problems of nuclear engineering and the related sciences," with emphasis on the "industrial usefulness" of atomic power.

The Council is constituted of eight leading engineering societies with a total membership of 170,000. The American Chemical Society, which has joined the engineers in the nuclear unit, has 70,000 members. Dr. John R. Dunning, Dean of Engineering at Columbia University, has been elected Chairman of the General Committee. Dr. Donald L. Katz, of the University of Michigan, is Secretary and Program Chairman. The General Committee on Nuclear Engineering and Science stated that it had invited the participation, as members, of organizations of physicists and others concerned with nuclear development.

The General Committee plans a Nuclear Congress to be held July 11–16, 1955 with an expected attendance of 1500. The holding of this Congress, however, is conditioned on the action of the United Nations on the proposal of Secretary of State Dulles for an international conference on the creation of a world bank of fissionable material for peaceful productivity.

"It is the earnest desire of the General Committee on Nuclear Engineering and Science to cooperate fully with such a program," said the new Committee's announcement. "If the United Nations designates a city in North America for a conference in 1955, we shall forego our own Nuclear Congress for that year and we shall be willing to accept the responsibilities for the civilian aspects of the meeting. If the UN conference is held abroad, our Nuclear Congress will be held in a city in the United States to be designated later."

Thermodynamics for Engineers*

By ALI BULENT CAMBEL

Associate Professor of Mechanical Engineering, Gas Dynamics Laboratory, Northwestern University

Probably the main objection to the present day presentation of thermodynamics is that it is antiquated. The thermodynamics that we teach is based on arguments set forth by brilliant men like Carnot, Clausius, Rumford, and Kelvin many years ago. This thermodynamics though "necessary" is no longer "sufficient." Today technology is such that the assumptions of the isolated system, the externally and the internally reversible process are restrictions which are too drastic and oversimplify the problems at hand. The thermodynamics that is needed now is much more general and in it rate processes are of great importance.

It seems to me that as teachers we commit a very serious error. Whenever we realize that what we do is no longer adequate we add a new chapter or a new course to explain what we think should be taught to the student. The result is that we have numerous courses some of which contradict one another and our teaching becomes a process of successive corrections of misconceptions which we impart our students. The standard defense for this type of an approach is that no student ever learns a subject well, unless he takes a more advanced one in that field to force him to understand the prerequisite. Frankly, I cannot believe that our students are that mediocre. I think that we should teach good, up to date thermodynamics once and for all and stop teaching material which we know is no longer absolutely correct or at best is trivial.

Teach Interwoven Discipline

I am also of the opinion that thermodynamics should be taught not as a compartmentalized course but as an overall, widely embracing discipline. We should definitely combine the courses of fluid mechanics, heat power laboratory, heat engines, heat transfer, thermochemistry and thermodynamics into one subject and teach this interwoven discipline as the student will encounter in industry. Just as a preliminary proposal I should like to toss out the topical sequence: 1) Hydrostatics and the concept of pressure; 2) the zeroth law and the concept of temperature; 3) heat transfer by radiation; 4) heat transfer by conduction; 5) heat transfer by convection; 6) thermodynamic properties and phase changes; 7) equations of state; 8) kinetic theory and the theory of mixtures; 9) fluid dynamics; 10) the first law of thermodynamics, first law analysis; 11) the second law of thermodynamics, second law analysis; 12) thermodynamic functions and thermodynamic equilibrium; 13) the third law of thermodynamics and third law analysis; 14) thermochemistry, thermoelectricity and the thermodynamics of irreversible processes.

Among other things this outline (probably consisting of a five semester sequence) strives to accomplish the following:

1) Vapors and gases and liquids are treated so that the student is not led to believe that these are different media, but it is emphasized that the same medium may behave as a gas,

* Reprinted from *Heat Power News & Views*, Vol IX, No. 39, May, 1954.

as a vapor or as a liquid depending on the conditions imposed upon it.

2) Fundamental theory and applications are treated concurrently. Thus for example all cycles would be discussed according to first law considerations while the first law is being studied. Then while studying the second law the principle cycles would again be considered one by one, but this time the restrictions imposed by this law would be taken up. Finally when studying the third law further restrictions would be considered. In this manner the student would thoroughly understand how the laws are used and why certain cycles are not possible. If my experience is any indication it seems to me that few students really understand how the fundamental laws dictate a certain cycle arrangement.

3) The heat power laboratory would run concurrently with the lectures and the student would perform experiments on subjects being discussed in class. This would obviously create trouble because of the undesirability of duplicating equipment. However, this can be overcome easily if we are tolerant and realize that every student does not need to perform a test on every device. Why not have different students test different engines. From the viewpoint of the fundamental laws it does not make much difference whether an internal combustion engine is of the compression ignition type or of the spark ignition type. Thus if we want to educate our students to thoroughly comprehend the fundamentals, one engine is as good as another. If however, we want to train our students to have dexterity in manipulating the controls of some gadget we should not pretend that we are graduating engineers but should admit that we are preparing technicians.

Conclusion

Finally, I would tie in the design sequence in its latter stages with thermodynamics in its latter stages. In the design of a heat engine there are many things which are perfectly possible thermodynamically but are not advisable because of limitations of machine design and metallurgy. Students should know these limitations and should comprehend engineering as it really is.

This suggestion that thermodynamics should be taught with all of its allied fields will be disputed by some who will say "Engineering today is too complicated and hence no man can be expected to understand it all." I disagree in part. It seems to me that engineering today is complicated and accordingly we cannot afford to be mere specialists.

The following four papers were presented in January, 1954 during the annual meeting of the American Association of Physics Teachers in the course of a symposium, "The Responsibility of the Physics Teacher in Engineering Education," under the chairmanship of Joseph H. Keenan, chairman of the AAPT Committee on Engineering Education. These four manuscripts are also being published by the American Journal of Physics.—Editor.

The Responsibility of the Physics Teacher in Engineering Education

By N. H. FRANK

Massachusetts Institute of Technology, Cambridge, Massachusetts

In approaching the subject of the responsibility of the physics teacher in engineering education, and the questions to be answered in this panel discussion, I feel it is necessary first to establish a proper frame of reference with regard to the division of responsibility between the physics teacher and the engineer. One must first ascertain just what are the broad objectives of a physics course in an engineering curriculum and how much time can be allotted for the attainment of these objectives. When these decisions have been made—and they should properly be made by engineering faculties—then, and only then, can one hope to obtain clean, definitive answers to the questions before us.

Without entering into all the ramifications pertinent to such considerations, it will be sufficient for the purpose at hand to determine to what extent, if any, it is expected that physics courses for engineers should form the beginning of a sequence of professional subjects. In other words, just how much *applied* physics belongs in such courses? It is my opinion that to such a question there is only one answer which can possibly hope to enable engineering education to meet the challenge of the rapidly changing and growing complex of requirements which it must satisfy. Physics, along with other science courses, should provide sufficiently deep and strong scientific roots to make possible healthy professional technical growth in whatever area of engineering a student chooses to cast his career. This calls for the elimination practically in toto of applied physics in physics courses for engineers. I realize that this view is diametrically opposed to the traditional role of science in engineering curricula and hence it is bound to be unpopular. But even were it wise to urge physicists to teach applied physics (and I believe that engineering teachers are the ones who are best suited to teach applied science), the rapidly growing body of scientific knowledge, the equally rapid decrease in the time interval between a discovery in pure science and its practical utilization, and the unprecedented rate at which modern physics is making itself felt in technology and industry, would mitigate strongly against such a course of action.

Pure Physics

In short, physics courses should be pure physics and applied physics should be taught by the engineers. If, and I shudder to contemplate such an event, applied physics represents all that would be desired in engineering curricula, then it should be taught entirely by engineers. Such an attitude would inevitably result in vocational training rather than engi-

neering education. Let us banish such thoughts from our discussion and face the following issue squarely: "How can physicists meet the challenge of imparting a strong and deep base in physics, including modern physics with all its rapid growth and increasing abstractness and complexity, without having available any appreciable increase in time to do the job?" Clearly, the mere addition of the factual matter of modern physics and of modern physical theory to the traditional courses can lead only to dilution and superficiality. I submit that we need surgery; we must be willing to cut out much of the traditional, albeit solid, subject matter of physics, use modern physics to supply the illustrations of the basic principles, shift the emphasis to the broad conservation principles and their implications, integrating them into a unified structure, and drop the conventional divisions of physics. These are harsh remedies, but no longer are they a matter of taste; failure to employ such remedies can only lead to a deterioration in the well-being of the patient.

I do not pretend to know just how to perform the surgery which is called for. In fact, there may be and probably will be a number of adequate solutions, equally good, in attaining the ultimate goal. It will be well if many solutions do exist, so that individual teachers can follow their own tastes and be guided by the interests and caliber of their own students in choosing the best course for them. In any event, one thing is clear; we must face this educational problem in the same spirit that we face any new problem in science. An objective experimental attitude devoid of prejudices, a willingness to learn by failure as well as by success, and an awareness that this type of problem constitutes a continuing research program for teachers at every level, are the necessary ingredients for clarification and progress in this otherwise perplexing and discouraging situation.

February 25, 1954

The Responsibility of the Physics Teacher in Engineering Education

By LLOYD P. SMITH

Cornell University

The matter of situations and problems to be faced by the teacher of physics for engineering students and the effect of his teaching on the technical competence and aims of the engineering student is fraught with complicated difficulties. This is evidenced by the continual discussion, the unhappiness on the part of some engineers about the teaching of physics, the threats to remove the teaching of physics from competent teachers in physics departments and replace this by the teaching of physics from the engineering or practical point of view within the college of engineering.

In my opinion, one of the most important reasons for this continuously unsettled state and lack of mutual satisfaction in this matter is due to a lack of mutual understanding of what the true objectives of engineering education and training really are in various schools. This arises in part because there is evidence that a good deal of uncertainty and confusion exists within a given engineering school in regard to the type of training it is expected that engineering graduates will on the average acquire. It is not possible to discuss the responsibility of the physics teacher in engineering education in an enlightened way unless one sees clearly the

objectives to be achieved by engineering education in various schools of engineering. It is fairly clear that the responsibility of a physics teacher is one thing if the engineering school under consideration really wants to turn out technically qualified engineers, and it is another thing if a school wishes to turn out students who will be qualified mostly for routine design, directed staff work, engineering sales and other applied specialties. Since I believe that a modern engineering college located within a university has the responsibility of providing the type of training which will turn out technically qualified engineers, I shall discuss the responsibility of the physics teacher on the assumption that it is the latter type of educational objective toward which a particular engineering school is striving. Before doing this a word or so is necessary to define what I mean by a really technically qualified engineer. The most important measure of a technically qualified engineer is the degree to which he can analyze and reach important technical decisions in non-routine engineering or technical situations. I am assuming therefore that he will have the ability to do considerably more than carry out routine designs of new structures or to handle repetitive engineering situations.

This ability to analyze a situation and bring to bear an extensive technical knowledge on the solution of modern problems differentiates the ordinary engineer from the productive and outstanding one. The basic physics which a student acquires and really understands has a direct bearing on this analytical ability. There is evidence that at present this ability on the part of a student increases rather rapidly during his first two years in engineering school and increases but little in the remaining college years. To the extent that this is so, the engineering training in later college years is deficient. If we take it for granted that it is desirable to develop this analytical ability during the course of an engineer's training, it becomes the important responsibility of the physics teacher to provide the student with a firm foundation of basic physics. He must not only supply him with the factual knowledge of the science, but most important of all he must inculcate the seeds of analytical skill, that certain something which allows an individual to first obtain a clear understanding of a situation and proceed to scientifically and technically sound conclusions about it. This is a particularly difficult thing to do at the present time. Much of a student's pre-college training these days places more stress on being able to give back to an instructor the material which is presented to him by means of a book or lecture. In other words the student is coached more than taught. Very little emphasis is laid on the analytical approach which I have just mentioned.

Poor Study and Work Habits

In preparing for college in this era, many students not only do not do very much thinking in contrast to memorizing but they have extremely poor study and work habits. This makes the task of the physics teacher in realizing the responsibility mentioned above all the more arduous. It seems to me that one of the most important things to do is to find a means of taking the rather poorly prepared student and providing him with the type of training mentioned above during his college career. A re-distribution of subject matter as between mathematics, physics, and chemistry may be required to realize this objective.

It is my firm opinion that mathematics, physics, and chemistry should be taught in these respective departments by teachers competent in their fields, who along with the engineering faculty have a clear understanding of the objective of the engineering school and the role that science is to play in realizing these objectives. I have no objection per se in transferring material in physics to schools of engineering when these subjects become more of the nature of applied subjects which are not necessary or particularly important in establishing the basis for a clear under-

standing of physics nor play an important role in developing the analytical ability of the student. This transfer has occurred before. For example, nowadays very little circuit work is done in physics but has become an integral part of the training program in electrical engineering. To take the basic work in physics, which is so important in the understanding of phenomena and important in developing the student's analytical ability into schools of engineering, is, I believe, quite the wrong thing to do. One reason advanced for transferring the teaching of mechanics, heat, electricity and magnetism and elasticity, etc. to engineers is that the only current research in these topics is being conducted in engineering schools and the most stimulating instruction will be given by instructors closely associated with such research. As far as stimulation and up-to-date instruction goes I would agree but I can not agree that all research in these fields, as I understand the term, is now being carried on by engineers. It is true that engineers are measuring heat transfer coefficients for numerous materials at a variety of temperatures, determining magnetic properties of materials, determining the properties of materials under stress and the like but what about the large amount of research concerned with the atomic and electronic mechanisms involved in the transfer of energy in matter, or the quantum behavior of atoms and electrons in matter which gives rise to ferromagnetism and properties possessed by ferrites or the migration of atoms which produce dislocations and their subsequent motion when a material is stressed leading to plastic flow, creep and the like, being carried on actively in a good many departments of physics? From the standpoint of basic understanding I do not think that this reason for transferring the teaching of the subjects mentioned above can be made to hold up. Another reason for making a transfer is to prevent overlapping and repetition of subject matter and to free more time in the student's curriculum for modern physics. The facts in this matter, as far as I know them, are that a really useful working knowledge of modern physics could not be given under such circumstances because the basic aspects of the subjects given in engineering, together with the concurrent development of the analytical approach is simply missing. Consequently the departments of physics would be required, of necessity, to build up the basic aspects of the subject anyway in a later period in the student's college course, at a period where most engineering schools have a full course schedule of their own specialties. If the objective in giving modern physics is to give a rather descriptive account of a group of phenomena in atomic and nuclear physics, this could probably be done. But the student would not obtain a working knowledge of modern physics which would be of much use to him in coping with the complex technical problems of the present day.

Training For Industrial Research

So far I have been speaking about the physics teacher's responsibility in the training of the usual engineer but not his responsibility or even the role of physics for the person whose career is to be in industrial research or advanced engineering development. The type of training required here is different from the usual engineer's training. This was very fully realized during the war, and as a result several new types of training programs have been established to fill in this gap. The answer to this type of training I believe lies in the establishment of engineering physics or engineering science curricula, where the emphasis is laid on the integration of three main technical areas: the basic sciences of physics, mathematics, and chemistry; the physics chemistry and metallurgy of engineering materials, generally; and engineering practice.

In this type of program the responsibility of the physics teacher is very great indeed. He must give the student in this program the opportunity to acquire an ex-

tensive knowledge of basic physics and help him to develop analytical ability to a high degree. In the Cornell engineering physics program this is accomplished in at least 36 hours of physics including a two-year course covering mechanics, wave motion, sound, heat, electricity, magnetism, and light, together with courses in thermodynamics and kinetic theory, analytical mechanics, atomic and nuclear physics, electronic properties of solids and liquids, advanced laboratory, and mechanics of continuous media. In this highly integrated program, the students fully realize from the very start that a good and thorough working knowledge of basic science is an important and integral part of their training. As time progresses they become even more fully aware of its potential usefulness in their work. In order to realize the objectives of this program, it would be quite impossible for the students to acquire their basic physics from courses in physics taught in the engineering college from an engineering point of view.

The most important point I wanted to make here is that for a competently trained engineer it is essential that he acquire sound basic knowledge of our most basic science, namely physics. And he must be helped to develop the analytical approach which is natural in physics. This I feel can best be done by association with people trained in physics within the department of physics. The success of a physics teacher in doing this depends on a clear and understanding knowledge of the engineering school's objective and his ability to cope with the inadequate preparation and working habits of our present-day students now entering the universities.

Physics for Engineers in the Mid-Fifties

By L. E. GRINTER

University of Florida

Physics has undergone a remarkable transformation in the past twenty five years. Engineering has passed through an equal or even greater change. Yet the physics taught today to engineers except in a few locations could have been taught and in the most enlightened spots was probably being taught in 1930. It is difficult to understand that this is in the best interests of the engineering profession. However, to reach a conclusion as to what approach to physics would be in the best interests of engineering education will require long soul searching and a far deeper analysis than this brief paper can be expected to make. Engineers will be satisfied if they see their colleagues in physics undertaking to determine cooperatively what physics should be taught to engineers in the mid-fifties. Of course, this is not a decision to be arrived at either by physicists or engineers working alone. It must be a cooperative endeavor, but the engineers would prefer to see the study spearheaded by physics teachers.

Increased Use of Engineering Science

We need not review the changes that have occurred in physics during the past fifty years, but the changes in engineering may not be so well understood. Engineering art is as ancient as civilization, but engineering science is not much more than a century old. It is little more than a hundred years since Squire Whipple developed the procedure of stress analysis for a simple truss. As pointed out by N. W. Daugherty, Mahan's textbook, "Civil Engineering," published in 1846, which was in use until nearly 1900, significantly does not give a method of cal-

culating stresses in trusses even though it has chapters on bridges and other structures. During the second half of the nineteenth century, when the pattern of the typical course in physics for engineers was being evolved, engineers were almost wholly dependent upon physicists for their background of science.

As is well known, engineering colleges evolved from departments of physics or of natural philosophy. In such early years engineers naturally looked toward physics as the source of their limited tools in engineering science. The physicists' struggle for recognition in the academic fraternity paralleled their own struggle. The eventual academic recognition of physicists foreshadowed the recognition of engineering as a learned profession. The evidence of recent years that engineering and physics consistently attract the highest student intellects to their curricula has broken down the last academic barriers. In many respects physics and engineering are one branch of learning but with different objectives and different emphases.

Throughout the nineteenth and the early part of the twentieth centuries engineers were able to apply engineering art to produce great advances without feeling the need for much engineering science. Elementary statics, dynamics, thermodynamics and electricity from physics served as a scientific background which most engineers used only intuitively to guide their applications of engineering art. Mathematical analysis was given scant attention in engineering offices. However, a slow growth in the importance of science in engineering was taking place. This influence led to the teaching of additional mechanics to civil engineers and somewhat later to additional thermodynamics for mechanical engineers. Electrical engineering was born with a stronger scientific interest than the older branches of engineering. Correspondingly, when chemical and aeronautical engineering developed, their curricula emphasized the viewpoint of applied science rather than art.

Research in Physics and Engineering Science

Graduate study and research in engineering showed a parallel growth. It appears that a Ph.D. degree given in civil engineering at Cornell soon after 1870 may prove to be one of the first doctor's degrees conferred in the United States. In any event, it indicates an early development of the spirit of research in engineering colleges. Since the engineering departments could not control the extensive procedures necessary to produce advances in the art of engineering, most research and graduate study was initiated in the fields of engineering science, i.e., in statics, dynamics, thermodynamics, fluid flow, heat transfer, electrical circuits, fields and electronics, physical metallurgy and the study of engineering materials. In early years, these studies duplicated rather heavily the interests of physicists, but the volume of research to be accomplished demanded the available manpower from both fields.

Depending upon whether one talks with electrical engineers or with physicists, electronics became a field of engineering science at some time between 1930 and 1940. Physicists had made many of the early contributions and many physicists continue to work in this field, but the large volume of electronics research both basic and applied now appears to have its primary source in engineering. Of course, electron physics is of primary interest to physicists. At one time the major research in elasticity, plasticity, elastic stability, fluid flow and heat flow came from departments of physics. One now turns to engineering journals for the large volume of research work in these fields. As an example, the *Journal of Applied Mechanics,* sponsored by ASME, is the most fruitful American source of theoretical research papers in mechanics. This journal was only established some twenty years ago.

It seems clear that physicists maintained a strong interest in and produced a major influence upon most of the fields of engi-

neering science until World War II when the research interests of so many physicists was reoriented by the development of nuclear energy. At that time one observed the transfer of the interest of physicists to contracts of the Manhattan Project, the disappearance of physicists without even a forwarding address, the closure or transformation of laboratories. Some of the previous researches of physicists were taken over by engineers. Elsewhere, in engineering the pressure of military need backed by unlimited funds led engineers to attempt to solve problems in engineering science which otherwise might have been left for leisurely solution by physicists. Once engineers found that they could also move forward the curtain of the unknown in those fields of science that form the immediate background of engineering practice they have shown no desire to withdraw. In fact, engineers have steadily increased their productivity of rather fundamental research in the engineering sciences.

The Contributions of Physicists to Engineering

It is fruitless to try to guess to what degree the interest of physicists will eventually be returned to the fields of engineering science. Clearly, the emphasis upon nuclear and particle physics and other fields of modern physics cannot be permitted to die or even reduce appreciably. Those agencies that finance research in the fields of modern physics will see to that. Research manpower is short in engineering, but there is very little hope that I can see for help from physicists. Instead, the number of engineers devoting their time to research in the engineering sciences is certain to increase slowly. In short, for those fields introduced in the typical one-year course in classical physics for engineers, the volume of relatively basic research produced by engineers appears likely to far outweigh the possible research of physicists. It also appears that engineers now inherently recognize their responsibility for research, both pure and applied, in the fields of engineering sciences. Conversely they recognize their dependence upon physicists for further knowledge of the nature of matter and of gravitation, energy and force.

It is this feeling of complete dependence upon physicists for the most basic concepts in engineering that has led well known engineering educators to question the traditional course in classical physics for engineers. ASEE has been trying to develop a pattern of engineering education to prepare engineers for scientific leadership twenty-five years hence. To put the matter in its simplest terms, engineering teachers have a chance to observe every engineer who completes the course in physics and they do not feel that these students carry with them sufficient basic knowledge of the nature of matter or of the molecular and crystal formation of materials or of gravitation, energy or force. Instead, the student carries to his engineering courses a slight knowledge of equilibrium, motion, heat and electricity and an even more casual understanding of light and sound. This understanding is so limited and so uncoordinated with engineering terminology and engineering thinking that I fear a majority of engineering teachers in mechanics and thermodynamics and even in electricity give the work in physics little weight or direct consideration in planning their courses. Hence, we have unplanned duplication in a short curriculum where every moment of classroom time is as precious as a drop of water in the desert.

Reduction of Educational Duplication

If duplication were the only question involved, it could be reduced if not avoided by engineering teachers themselves. Or more effectively, physicists and engineering teachers could meet together in regularly scheduled conferences to eliminate undesirable duplication. However, one doubts that anything less than a planning conference every semester could

achieve and maintain any real semblance of coordination between the teaching of a dozen physics teachers and fifty or more engineering instructors who receive the product of physics instruction. Such coordination becomes a problem of great complexity. Two colleges are usually involved. Tradition is rampant. Up to a third or more of the instructors involved may change in a single year. There are objectives beneath the surface that influence attitudes unduly. For example, physicists unhesitatingly admit that the loss of teaching hours for their graduate assistants in handling sophomore engineers would handicap physicists' research. Engineers too often approach the problem of coordination with the preconceived notion that anything a physicist can do for an engineering student can be done better in an engineering class. Such viewpoints must be met and overcome.

Teaching Modern Physics to Engineers

There is something of far greater importance than relieving duplication to be accomplished by a modern approach to physics instruction for engineers. Physicists, particularly young physicists, do not hesitate to say that after a first or second experience the teaching of classical physics to engineers becomes a chore. Some older teachers take a reversed viewpoint, but it is clear that these indivduals are valuable professional teachers to whom subject matter has become of less importance than teaching procedures. We need such able teachers. They can present equally well more modern subject matter even though they may not be research workers themselves. Although the sophomore or junior engineer is not ready for graduate work in physics, he is fully able to acquire a useful knowledge of nuclear physics and physics of the solid state when presented at an appropriate level. It should not be forgotton that engineering students, on the average, have minds fully equivalent to those of science majors and that no watering down of scientific content should be necessary in a physics course for engineers.

The Committee on Evaluation of Engineering Education of ASEE has concluded with remarkable unanimity that a knowledge of modern physics is essential for engineers. Doubtless, physicists generally will applaud this decision. Doubtless, too, most physics teachers would recommend an additional year of physics study to accomplish this objective. Unhappily, that approach is not likely to accomplish the objective of an understanding of modern physics for engineers as long as the four-year curriculum continues with its strong limitations upon time for the study of any individual field.

Individual Solutions Necessary

It is not possible for anyone to devise a universal solution to the problems that have been presented. There are more than a hundred and eighty institutions with accredited curricula in engineering. There are many variations in the way physics is taught to engineers. Each institution must study the matter and devise its own solution to the need of engineers for a knowledge of modern physics. Certainly a real attack should be made on the factor of duplication with contributions and concessions from both engineering teachers and physics teachers. It appears that a logical criterion for determining where a given topic should be taught can be found in the main source of the research in the field. If it can be demonstrated that the research in a given field is being conducted largely by physicists there need be no fear that engineers can or will desire to take over the undergraduate instruction therein. The department that is responsible for the research in a given subject should produce the greatest stimulation of either undergraduate or graduate students in that field.

The conflict that one sees in the present situation is that the subjects of greatest interest to physicists and in which they are so intensely involved with research are

not being taught to undergraduate engineers. Nuclear and particle physics and physics of the solid state are left for study by physics majors and by graduate students. A very large percentage of engineers graduate without contact with these subjects. It seems to me that the opportunity to teach these subjects to engineers would provide a real stimulation not only to the engineering students but to those physicists who find the teaching of mechanics, thermodynamics and electricity at the most elementary level a little dull.

The Basic Values of a Study of Physics by Engineers

As adjustments are considered engineers should be quick to agree that there should be no reduction in the total time which engineering students should give to study within departments of physics. In fact the Committee on Evaluation of Engineering Education has recommended that added time be devoted wherever possible in engineering curricula to the study of the basic sciences. The present amount of time devoted to physics is a minimum for indoctrination of engineers into the thinking, the viewpoints, the attitudes, and the research methods of physicists.

The subject matter in physics of greatest value for engineers will be that subject matter which acts most effectively as a vehicle for teaching the viewpoints, attitudes and methods of modern physics research. A second reason why the engineering student needs a working relationship with modern physics is that it will be his job a decade or two decades later to devise the processes, mechanisms and plants that will put modern physics to work for the welfare of mankind. Only with humility and understanding can we properly approach our joint responsibility for achieving an education for engineers in the mid-fifties that may bring forth a new industrial revolution.

The Responsibility of the Physics Teacher in Engineering Education

By HOMER L. DODGE

President Emeritus of Norwich University

The problem of the relationship between pure and applied science has been with us for a long time; and it will remain so, for it is one of those problems for which there is no perfect or final answer. The best that can be expected is a *modus vivendi* between physicists and engineers resulting at any given time from whole hearted cooperation and a willingness to give generous consideration to differing points of view. It is natural that there should always be persons whose primary concern is the application of science for useful purposes and other persons whose interest lies primarily in science for its own sake. Fortunately there will be others with varying degrees of interest in both fields; but both engineering and science would suffer if there were not those to which one or the other is the burning concern.

With this situation, there is no possibility that either group will have the last word or find a way for working harmoniously with the other that will be completely satisfactory to it. In their dissatisfaction the engineers are tempted to take over the teaching of physics and so remove the teaching of the subject from physicists closely associated with, and participating in, the current developments of their science as a living subject. Engi-

neers know how essential it is that engineering teaching be carried on by men who spend part of their time in active engineering practice; they should realize that science also must be taught by persons to whom it is a vital living thing. It is the fault of physicists that those engineers who appreciate this fact are rightfully disappointed in the way in which physics is currently being taught to engineers. And the AAPT merits criticism for not having accomplished more in vitalizing the teaching of physics to engineers in the twenty-four years of its existence.

The cure will come when engineering educators make up their minds wholeheartedly to devote a major part of their efforts toward turning out really professional engineers. There has been little evidence of such a desire, for it demands more of a reorganization of American engineering education than engineering educators have been willing to undertake. That it has not been more seriously considered is surprising, for the model from which lessons could be gained, even though it might not be desirable to emulate it in all details, has existed in Europe for years.

Principles vs. Practice

In the summer of 1926, I made a study of engineering education in Europe, visiting some dozen or more of the leading institutions in England, Denmark, Germany, Austria and France. Everywhere I was impressed with the fact that engineering in Europe is regarded as applied *science*. One sought in vain for anything like our departments of civil, electrical or mechanical engineering; but had no difficulty in finding great departments of mathematics, physics and chemistry where the students spent their time learning the fundamental science upon which all engineering must be based. In the laboratories the emphasis was on *principles* of engineering rather than on *practice*. It was explained that no educational institution could possibly keep its equipment up to date sufficiently so that students could learn current practice; so they were content to make the students sufficiently familiar with heavy machinery so that they would not feel too strange when confronted with the actual work of their first jobs.

I suppose it was from this experience that I formulated the principles that were applied so successfully at the University of Oklahoma in our engineering physics curriculum which was devoted largely to preparation for geophysical prospecting for oil.

In our curriculum, including graduate work, there was only one course that was not a regularly offered course in physics, mathematics, geology, engineering or other subjects. This was a three-hour, one-semester course in applied geophysics. For this course we had available excellent field equipment, but we told our students that there was something wrong with the company if, when they got their first job, they found still in use any of the equipment we had been able to show them. And that if, in the course of a year, they had not made obsolete the equipment and methods which they found on arrival, there was something wrong with them or the preparation we had given them. Our better men were soon operating their own companies or organizing instrument companies to manufacture equipment of their design.

As already suggested, we can learn a great deal from European engineering education, but its spirit and methods should be used to supplement and correct our methods rather than as a substitute. There is an ability, energy and drive, that American engineering graduates have, to *get things done* that is not to be found in Europe. This came out in a conversation with a German professor who would not let me forget the virtures of our American way. "Our men," he said, "are better trained than yours, but they are so thoroughly trained and so scholarly in their approach that they seem never to be quite ready to do the job. There is always some additional refinement that must be made before they start. Our graduates can

make almost perfect designs for bridges and dams but somehow they don't get them built. On the other hand, your graduates, inadequately prepared for many of the projects that they undertake, do manage to work out designs, doubling the factor of safety with the hope that it will take care of their deficiencies, and get the structures built. Luckily, not many of their bridges fall and not many of their dams go out with the first flood. Something that combines what you have in America and what you have discovered we have in Europe is what you need to make American engineering the foremost in the world."

As a member of the ASEE for over twenty-five years, I have observed no serious attempt to develop a program for the education of really professional engineers on an equal footing with physicians, lawyers and ministers or, for that matter, men trained in the disciplines for which the degree of doctor of philosophy is regarded as a professional prerequisite. In none of these fields is the attempt made to build a professional education on a high school preparation. And yet that is what engineering educators are still trying to do.

Some of the leaders, realizing its inadequacy have been playing with the fifth year, others have been trying to make up for general cultural inadequacy by doses of a few 3-hour "Social Studies" pills while others have been pressing for "research" and "graduate study," not realizing that the usual four-year engineering course furnishes no sound foundation for genuine graduate study and research.

With other professional fields dissatisfied with any preparation less than a sound, broad liberal college education, with a grounding in the fundamentals upon which the profession rests, whether they be natural science, political science, or philosophy and psychology, engineering has persisted in the fallacy that professional engineering education can follow a high school preparation.

Inadequacy Being Recognized

It is true that the inadequacy of the present course in engineering as a foundation for graduate study is being recognized in the talk about a professional-scientific course. But the total inadequacy of graduate work founded on such a course to produce professional engineers able to stand on an equal footing with other well trained professional men has not been brought out.

Thanks to the imagination, energy and persistence of American youth, many of them have found their way to a solution of this problem that has been so baffling to experienced engineering educators. Finding out for themselves the inadequacies of their engineering preparation, they change over into mathematics, physics or chemistry for graduate work. Or it may be that they finish an undergraduate program in physics or mathematics and, feeling the urge to go into applied science, seek out one of the engineering colleges that lead in graduate work. Others plan from the beginning what the engineering educators should plan for all who are expected to become truly professional engineers. Knowing that they want to be engineers, but that they also want to be educated men, they first complete a college education and then move into engineering, or perhaps they take advantage of a transfer to an engineering college at the end of three years, as has wisely been provided for by some institutions. And finally, a very small number of prospective engineers enjoy the excellent professional preparation provided by curricula in engineering physics (or the equivalent) which, for over a half-century, all too few departments of physics have had the imagination to provide. But this group is not the subject of these remarks.

Fundamental Change in Approach Needed

If I had at my command several million dollars, I could think of nothing better to do with it than to found a graduate school

of engineering. The requirement for admission would be graduation from a liberal arts college, with a reasonable amount, but not too much, mathematics, physics and chemistry. Properly staffed and equipped, such an institution would produce real professional engineers, and its influence on engineering education would be profound. No combination of "professional-scientific" and graduate study is going to produce the equivalent. Insofar as any program of engineering education fails to do this, it will fail to provide true professional training.

When programs of this general type have become the ideal of engineering education, physics will not have to be concerned about its place in engineering curricula. Until such a fundamental change in approach is made, however, engineering educators will continue to try to effect a cure by treating symptoms of a disorder instead of getting to the root of the trouble.

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Report on ASEE Summer Institutes on Inclusion of Modern and Solid State Physics in the Curricula of All Engineers

By CLIFFORD BECK

Head of Physics Department, North Carolina State College

Four separate conferences jointly sponsored by ASEE and NSF, each composed of engineers and physicists from industry and academic institutions, were held in the summer of 1954. Two of these conferences dealt mainly with the advisability of including a portion of basic, elementary Solid State Physics in the curricula of all engineers. The other two dealt with the same question relative to Modern, Atomic, and Nuclear Physics.

In each of the two series of conferences, the first was a "Closed Conference" limited to about 30 invited participants who acted as an exploratory survey team to identify and select matters of importance in the general area of interest, and thus to define an agenda for the subsequent Open Conference of volunteer participants in the subsequent meeting. The two Open Conferences were each attended by 125–150 scientists, engineers, and industrial representatives.

The Open Conferences were four days in length. Formal presentation of opinions and suggested materials by top-level scientists and engineers from all over the country alternated with discussion periods —which were most vigorously utilized.

The discussions were by no means limited to the topics which might be considered closely related to the central theme. Individual opinion ranged almost from the one extreme of eliminating all physics from the curricula of engineers to that of eliminating all engineering courses from the curricula of engineers!

On the other hand, the topics relevant to the main problem of modernizing and reassessing the scope of chemistry and physics which might desirably be included in the curricula of all engineers, did receive lengthy consideration, and there was surprising unanimity of agreement on the major conclusions reached by the conferences. These conclusions, as recorded below, are chiefly those characterizing the opinions deriving from the Open Conference on Modern Physics. It is understood that very similar conclusions were arrived at by the Conference on Solid State Physics.

1) It was heartily reaffirmed that incorporation of the *methods* and *techniques,* as well as the basic principles and subject matter of chemistry and physics, is essential in the training of engineers. It was felt that re-orientation of presentation of the subject matter of these basic subjects to resemble the presentation used by engineers would defeat the major values of the courses.

2) It seemed inescapable that the scope of chemistry and physics today is much greater than it was a few years ago. There derives immediately from this fact a choice of two alternatives: (a) expand the general physics courses so that adequate attention could be given to more subjects, (b) arbitrarily eliminate some subjects and concentrate more attention on the ones remaining.

The conclusions of the conference represented, as might have been anticipated, a

compromise between these two alternatives.

A. Opinions on revision of general basic courses fell into two categories:

(1) eliminating or minimizing subjects not related to fundamental principles and not essential to development of subsequent concepts, and (2) modernization of illustrative examples and inclusion of up to date problems from modern physics and chemistry. It was the general consensus, however, that sufficient curtailment of basic classical physics to permit inclusion of adequate amounts of modern physics could not be done without serious compromise of objectives.

The discussion of modernization of the basic chemistry course, by Dr. Linus Pauling, contained the major thesis that the approach today should be from the viewpoint of *structural concepts*, based on current knowledge of *atomic* components and behavior. This is in contrast to the *descriptive* approach to chemical reactions widely used, formerly and currently.

B. Addition of new material, beyond the scope normally included in an up-to-date first course in general physics.

It was recommended that subject matter of a scope roughly equivalent to a 3-semester hour course on topics in Modern Physics such as those listed below be included above the general physics course level in the curricula of all engineers:

(1) Atomic Structure of Matter
  (a) Kinetic Theory
(2) Fundamental Particles
(3) Quantum Theory of Light
(4) Atomic Structure
  (a) Energy Levels
  (b) Spectroscopy
  (c) Periodic System
(5) X-Rays
(6) Wave Nature of Matter
  (a) One Dimensional Wave Equation
(7) Atomic Nucleus
(8) Molecular Structure
  (a) Valence Bonds
(9) Nuclear Structure—Elements, isotopes, elementary particles
(10) Binding Forces
(11) Binding Energy Curve
  (a) Mass-Energy Relation
  (b) Radioactivity
  (c) Nuclear Reactions
  (d) Fission, Fusion
(12) Neutron Chain Reaction
  (a) Heat—Power
  (b) Radiation—Interaction with matter
    Radioisotopes
    Breeding
  (c) Fission Products

It was also recommended that subject matter of a scope roughly equivalent to a 3-semester hour course on the topics in Solid State Physics listed below be included above the general physics course level in the curricula of all engineers:

(1) Crystal Structure
(2) Binding Forces and Crystal Types
(3) Mechanical and Thermal Properties
(4) Electrical Conductivity
  (a) Metals
  (b) Semiconductors
  (c) Salts
(5) Dielectric Properties
(6) Magnetic Properties
(7) Surface Effects
(8) Phosphors and Photoconductivity

(3) The strong suggestion of Dr. Pauling that basic chemistry be approached from a structural concept basis, with considerable prior effort being devoted to the necessary principles of atomic structure and electron behavior, the obvious necessity of including atomic structure and electron behavior in general physics, and the recommended inclusion of this same material in further detail at a higher level, led to some suggestions that collaboration of chemistry and physics teachers at the outset might lead to satisfactory instruction in these topics without undue overlapping and repetition.

(4) There was apparent in the conference a strong opinion favoring em-

phasis on basic science and basic engineering training at the undergraduate level, to the exclusion of courses related to specialization in restricted fields. Several serious opinions were expressed that attention should be given to *one* common undergraduate curriculum, containing a fair latitude in elective choice, of course, for *all* engineers. No dissent from these opinions, or from others proposing a common curriculum for at least three years, was voiced. By these plans, specialization and diversion of interests would be provided at the graduate level or by industrial companies after employment of the student.

(5) There was little dissent from the opinion that there is now no unique combination of activities which would distinguish Nuclear Engineering as a separate professional category. Instead, it was recognized that what is now called Nuclear Engineering is largely the application of orthodox engineering practices to a new technological area. It was also recognized, however, that some percentage of engineers practicing in this new area, variously estimated at 1% to 15% by 1970, would require training in nuclear processes and techniques beyond those generally provided for engineers. Further, it was noted that there is spontaneous and spreading use of the designation "Nuclear Engineer" even to the extent that several professorships in Nuclear Engineering have already been established.

Nevertheless, it was commonly agreed that establishment of a specialized course of study in Nuclear Engineering at the *undergraduate* level would be contrary to the recommended trend toward less emphasis on specialization at this level. It was the opinion instead, that such special training as would be needed, for as many men in this new area of application as might be required, should be provided at the graduate level.

The specific recommendation was, that "all *engineering schools* should give continual attention to the possibility and need for professional education in nuclear technology, especially at the graduate level."

Two factors were identified which tend to conserve the present over-emphasis on specialization in training of engineers at the undergraduate level: (1) the status quo of strongly established administrative lines on fields-of-engineering departmental basis, and (2) the insistence of employers in hiring graduating students according to specified engineering categories.

Comments on Nuclear Engineering in the Open Conference

It is our experience in our programs at North Carolina State College, and is in accord with our general opinions on engineering education, that development of nuclear engineering subjects and techniques in the training experience of students is most desirably provided at the graduate level. The sequence of an undergraduate training in some usual science or engineering field, followed by a master's program in Nuclear Engineering, constitutes an optimum combination. In general, as might be expected for such transfer students, it has been found that more than one year, and sometimes two, is required for completion of a satisfactory master's program in Nuclear Engineering. Preparatory courses in basic science and mathematics for the engineers and in essentials of engineering for the science students are usually required before the serious courses in applied nuclear processes are scheduled.

The general theoretical opinion of engineering educators today is that more basic scientific and generalized engineering training is needed at the undergraduate level for engineering students. The author of the undergraduate curriculum in Nuclear Engineering at North Carolina State College strongly concurs in this opinion, though, superficially, the designation of a course of study at the undergraduate level as Nuclear Engineering might appear to be the converse.

Actually, as has been pointed out in several ASEE and other meetings (Fon-

tana, Oak Ridge, Ann Arbor, Northwestern), the undergraduate curriculum designated as Nuclear Engineering contains more basic science and general engineering courses, and less material of specialized nature than can be found in almost any other engineering curriculum. The course distribution more closely approximates what might be called Engineering Physics than one of the usual engineering curricula.

Despite this however, there still seem to be very strong reasons for maintaining, at least for the present, the designation of this undergraduate program as Nuclear Engineering.

(1) This designation has strong attraction and motivation influences on the students. The course is well known to be "tough" but above-average students in increasing numbers are attracted, and the challenge of endeavor in an area of technology called Nuclear Engineering seems to have significant incentive value.

(2) The employer demand for students with "Nuclear" designation greatly exceeds the supply, and salaries significantly higher than obtained by other engineering graduates are offered.

(3) The course of study is fundamentally a sound one, whatever its designation, and provides a commendable foundation either for further work at the graduate level or for adaptation into research or engineering teams of an employer.

Perhaps eventually the pessimistic views will be vindicated of those who hold that the advent of significant beneficent applications of nuclear processes will be slow in developing and minor in scope. I believe otherwise. The commitment our government has made to a major effort in development of power from nuclear fuel as an important factor in our international relationships, the urgency of the need for power in many countries which could potentially be fulfilled by nuclear fuel, and the infiltration of nuclear applications throughout our industrial enterprises as is sure to occur, together with the attendant new applications likely to develop, cannot fail, in my opinion, to present a continuing demand for men well trained for these tasks. Training for such men must include instruction in the particular subject matter and methods peculiar to applied nuclear phenomena. For want of a better name, the convictions of engineering pedagogy not withstanding, such men are likely to be called Nuclear Engineers.

For these reasons, at least until sufficient reason for other action appears, we shall continue to train students in the subject matter and techniques of applied nuclear processes, beyond their sound indoctrination in basic science and engineering disciplines, and shall likely call these men Nuclear Engineers.

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A Curriculum for Technical Editors?

By CHRISTIAN K. ARNOLD

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Probably the professional field most widely ignored by the colleges and universities of the United States today is that of technical editing and writing. To my knowledge, no school in the country offers a definite, integrated curriculum to prepare students for positions in this field.

It is difficult to see why this field is so largely ignored. Surely it is not because the field is too limited to justify establishing a curriculum for it. It is readily apparent that the technical editor has become an integral part of almost all organizations engaged in research and development. The tremendous number of such organizations is indicated by the estimate that more than $3 billions were spent in the United States in 1952 alone on research and development. In addition, technical editors and writers are needed by publishing firms, professional journals, trade magazines, and newspapers. In the field of "popular" writing, both of articles and of book-length publications, it is generally believed that the least crowded field is that of science and engineering, not because of a lack of demand for such writing but because of a scarcity of capable technical writers. The field, then, that would be served by such a curriculum is obviously larger than those served by many of our traditional curricula: the classics, archaeology, and anthropology, for instance.

The Sandia Corporation, the General Electric Company, and the Sperry Gyroscope Company are only a few of the organizations that have advertised nationally month after month in an effort to recruit technical editors and writers. A Civil Service Commission serving five government-operated laboratories on the west coast advertised for a technical editor at the GS-11 level ($5910 annually) for well over a year without finding a person capable of filling the position. A medium-sized eastern laboratory advertised nationally for a technical editor for several months and finally paid a man moving expenses from California in order to fill the position.

This need is easily explained. Engineers and scientists can no longer afford to write just for each other, if indeed they ever could. In fact, the demand for an ever greater degree of specialization makes it progressively more difficult for one scientist to understand another. At the same time, today's greater interdependence of the sciences makes it necessary for each scientist and engineer to rely on the works of others for the advancement of his own studies. In addition, because research and development have become such a big business, it is seldom possible for those who administer the programs to be experts in each of the many specialized fields represented in the programs for which they are responsible. To guide his decisions, the administrator must have reports that are not merely accurate but also understandable to him even if he is not an expert in the technical field involved. Science, too, is an important and dynamic governing force in our civilization, and the technically trained person has a grave responsibility to translate his work into general human terms.

Time Is Precious Commodity

Because the time of our scientists and engineers is one of our most precious commodities, it is foolish to require them to

be forever translating the processes and results of their specialized thinking into the common language. It is here that the technical editor and writer is most useful. He stands between the technically trained person and his readers (other scientists and engineers, the administrators, and laymen) a representative of both. His special job is to fill the gap created by the forces that make it, at the same time, more difficult and more important for the scientist to communicate with those outside his own particular field of specialization.

It should be noted that increased specialization increases the need for technical editors in still another way. The necessity for specialization has the effect of crowding training in composition into such a small corner of the technical curriculum that it is doubtful whether a Julian Huxley, a Ruth Benedict, or a Waldemar Kaempffert could be produced in our schools today.

The need for a special curriculum is emphasized by the confusion that exists among those who hire technical editors as to what they are looking for. This confusion arises because technical editing and writing require training in two areas rarely combined in a college career. A student majoring in composition or journalism, for instance, seldom takes enough hours in technical courses to convince a director of a research laboratory that he should be entrusted with the preparation of highly scientific documents for publication. On the other hand, students majoring in engineering or one of the sciences rarely take any composition beyond the freshman level, except, perhaps, one 2-hour course in report writing. Such training is obviously inadequate preparation for the job of editing of any sort.

This difficulty in finding adequately trained technical editors and writers has led to pronounced disagreements as to what one should look for when trying to find editors. Recently an administrative editor of a west coast laboratory flatly stated that an editor without an extensive technical background was of absolutely no use to him. On the other hand, Dwight Gray, head of the Technical Information Division, the Library of Congress, recounts that an editor with whom he worked during World War II performed "real editorial miracles with technical manuscripts" despite the fact that she had had no training in science.* The head of an editorial group at another west coast laboratory, who has worked in the past with editors trained either in English or in technical fields but never in both, has stated that his experience indicates the better editors are those with broad training in the liberal arts. Yet the advertisements of several large industrial laboratories indicate that a degree in science or engineering is required of their technical editors and writers.

These disagreements exist only because the combination of training indicated as desirable by the disagreements themselves cannot be found consistently. The man who received his training in technical fields will not be a very successful editor until he has mastered the tools of editing, regardless of the soundness of his technical background. No amount of natural fluency will qualify him without such training. Too, the man trained in composition cannot give maximum assistance to the scientists and engineers with whom he works if he does not understand their language and attitude and the fundamental concepts of science in general. The intelligent person with the desire to do so can become a successful editor from either original training, but such on-the-job training is inefficient both for the organization and for the individual.

Integrated Curriculum

An integrated curriculum could be devised rather easily to resolve all these conflicts, as the conflicts themselves indicate

* Dwight E. Gray, "Editing Technical Reports," Workshop on Production and Use of Technical Reports, Catholic University of America, Washington, D. C., April 13–18, 1953.

the subject matter of such a curriculum. The backbone of the curriculum would consist of thorough basic training in the tools of both the editor and the scientist: composition, physics, mathematics, and chemistry, as a bare minimum.

Courses beyond the basic ones of first-year composition, mathematics, physics, and chemistry would be selected or designed to give the student (1) a thorough training in the editorial tools needed by the technical editor, (2) a sympathy with and a working knowledge of the rules by which scientists and engineers work, and (3) a technical background sufficiently broad to enable him to follow intelligently the thought of the publication he is given to edit.

Skill in the use of language as a means of communication is, of course, fundamental and would necessarily underscore all other strictly editorial training. However, skill in communicating by various means other than language would have to be stressed somewhat more in the training of a technical editor than in that for other editors. Such means would include mathematics, photography, drawings, documentary films, and, especially, tables and charts. Special types of writing in which the technical editor would need training include progress and completion reports, articles for professional and trade journals, news and publicity releases, information and recruiting brochures, and documentary film scripts. In addition, the editor should be given a sound introduction to proofreading, the principles of layout and art work, methods of reproduction, technical photography, and methods of literature research.

On the technical side, a somewhat wider choice could be offered the student. Training in strictly technical courses beyond the basic tool subjects, especially in the particular field of most interest to the student, is absolutely necessary; but specialization secured at the expense of a broad training would be harmful rather than helpful. Courses in history, law, social science, economics, and philosophy, with particular emphasis on the role of science and engineering in our civilization, would perhaps be at least as valuable as the strictly technical ones.

Such a curriculum would not be difficult to establish in most of our colleges and universities. The job would be somewhat easier to accomplish in those schools in which a separate department of English is maintained in the school of engineering, because the necessary liaison between the ordinarily separated fields would have already been established. To be most effective, however, the curriculum should be set up at a school that maintains a fairly large research and development program. A situation of this sort would offer the advantages both of the experience and knowledge of working technical editors and of an editorial laboratory in which trainees could work on actual publications in a real-life editorial environment. Many colleges and universities are equipped today to carry out such a program.

Such a program would satisfy all the conflicting requirements for a technical editor, including that which Dwight Gray lists as a "must," the proper general attitude of the editor toward the scientist and engineer authors with whom he works.

Is Calculus a Perfect Tool?*

By KARL MENGER

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EDITOR: A specialized article of this type is somewhat of an innovation for the JOURNAL although it stresses pedagogy of the utmost importance. The reaction of the readers is invited to guide future decisions.

This paper describes a point of view adopted in an experiment in the teaching of calculus and its applications to science and engineering which, for the past three years, has been carried out at the Illinois Institute of Technology. Courses along the lines here described are offered only on an elective basis. The number of attendants averages fifty per term. The majority are students of mechanical and electrical engineering; next in number are mathematics and physics majors. The groups include a few beginners; most of the attendants had previous training in calculus along traditional lines; about one quarter are graduate students. Evening sections are attended by numerous engineers working in industry. At the end of the term, attendants are asked to turn in (anonymously) comments on the course. Practically all of them emphasize that their understanding of calculus and its applications has been greatly enhanced; in fact, many say that now for the first time they really see "what calculus is all about."

* * *

Calculus is one of the greatest of intellectual achievements as well as one of the most powerful of scientific tools. Masters of mathematics and science have used this tool with virtuosity; but they depended on their insight and experience; they did not describe all their procedures in articulate rules. Hence, in applying calculus to science, it is necessary to fill certain gaps in the process by use of intuition. A beginner's intuition is unreliable.

Six points which seem to be in particular need of clarification can be summarized as follows.

I. *The Equivocal Use of the Term "Variable"*

The letter x in

$$(1) \qquad \frac{2}{x^2-1} = \frac{1}{x-1} - \frac{1}{x+1}$$

is what mathematicians call a variable, more precisely, a *numerical variable;* that is to say, x stands for any number of a certain class of numbers, called the scope of x, namely, for any number $\neq 1$ and -1. Since the scope of a numerical variable is its only significant feature, x in (1) can, without any change of the meaning, be replaced by another letter standing for any number $\neq 1$ and -1 (say, by a). Moreover, x can be replaced by any number belonging to the scope (say, by 3).

The temperature of a gas, the distance travelled by a falling object, and the perimeter of a sphere are examples of what scientists and engineers call variables. We will refer to them as *variable quantities* (briefly, v.q.'s) and thus avoid an equivocal use of the term variable. Even though the temperature of a gas and the letter x in (1) belong to different worlds, v.q.'s and numerical variables have often been confused.

* Presented at annual meeting of ASEE, University of Illinois, June, 1954.

II. *The Lack of Mathematically Usable Definitions for Variable Quantities*

But what are v.q.'s? A v.q. assumes numerical values, and the class of all its values is called its range. However, that range is not the only significant feature of a v.q., since v.q.'s with the same range cannot, in general, replace one another. For instance, in the formula for the volume of a sphere, the radius cannot be replaced by the perimeter, even though both v.q.'s have the same range, namely, the class of all positive numbers.

A v.q., in contrast to a numerical variable, has also a domain. In the case of a physical v.q., that domain consists, primarily, of acts of specific observation. Each value of the v.q. is paired with such an act, the value being the numerical result of the act.

We will define a physical v.q. as a class of pairs of the form "act, result." For instance, the temperature, t, of a gas in degrees C. is the class of all pairs $(\gamma, t(\gamma))$ in which the first member, γ, is an act of reading a thermometer, calibrated in degrees C., and the second member, $t(\gamma)$, is the number read as a result of that act.[1] Similarly, the pressure, p, and the volume, v, of a gas in certain units are defined as classes of pairs $(\gamma', p(\gamma'))$ and $(\gamma'', v(\gamma''))$ of the type "act, result" of (manometric and volumetric) observations. The time elapsed since the beginning of a process is a class of pairs in each of which the first member is an act of reading a timer set in motion at the beginning of the process, and the second member is the numerical result of that act.

The abscissa of a point in a physical plane with a Cartesian frame of reference (such as a blackboard with two perpendicular chalk lines, a foot being the unit of length, or a modern city with a street and an avenue, a city block being the unit of length) is a geometrical v.q.; it is the class of all pairs $(\pi, x(\pi))$ for any point π of the plane, where $x(\pi)$ denotes the distance (in the chosen unit) between the origin and the projection of π on the first axis of reference. We denote this class of pairs[2] by x.

The preceding and countless other examples can be summarized in the following general definition. A variable quantity u with the domain A (where A is a class of elements whatever) is a class of pairs $(\alpha, u(\alpha))$ in which α is any element of A and $u(\alpha)$ is a number associated with α, called the value of u for α.

III. *The Lack of a Traditional Symbol for the Identity Function*

V.q.'s whose domains are classes of numbers are called functions. An example is the logarithm of a positive number, that is, the pairing of the number *log* x with any number $x > 0$ or, more precisely, the class of all pairs (x, *log* x) in which the first member, x, is any positive number. This v.q. is called the logarithmic function; it is frequently designated by its value for x, that is, as the function *log* x. But just as one uses the expression "log tables" rather than "log x tables" he may refer to the logarithmic function as the function *log* rather than the function *log* x and designate by *log* x the value of the function *log* for x.

Another important example is the square of a number, that is, the class of all pairs (x, x^2) for any number x. The "2" to the right above x indicates the square of x. But no one would understand a reference to the function "2". In fact, there does not exist any traditional symbol for the square function itself—apart from its value for x—nor one for the all-important identity function, i.e., the class of all pairs (x, x).

We will denote the identity by j and

[1] Physicists gradually extend the domain by including extrapolations and computations based on observations—operations leading eventually even to the temperature of the sun 2 million years ago.

[2] Clearly, the abscissa which we symbolize by an italic x is altogether different from the numerical variable in (1), denoted by a roman x.

the nth power by j^n. The values of these functions for x are $j(x) = x$ and $j^n(x) = x^n$; for instance, $j^2(3) = 9$. What is gained by the introduction of these symbols?

If $Df(x)$ denotes the value for x of the derivative, Df, of the function f, then the following formulae hold for any x (the second, for any $x > 0$):

$$(2)\quad \begin{aligned} D\ sin\ x &= cos\ x, \\ D\ log\ x &= j^{-1}(x) = 1/j(x), \\ Dj^n(x) &= nj^{n-1}(x). \end{aligned}$$

Here, x is a numerical variable and, just as in (1), x can be replaced by another letter (say, by a) or by a number of the range (say, by 3). In contrast, the traditional symbol $D\,x^n$ links the function and the numerical variable in such a way that x cannot be replaced by either a or 3. Therefore the values of the derivatives which we denote by $Dj^n(a)$ and $Dj^n(3)$ are traditionally symbolized by $(D\,x^n)_{x=a}$ and $(D\,x^n)_{x=3}$, even though one writes na^{n-1} and $n3^{n-1}$ rather than $(nx^n)_{x=a}$ and $(nx^{n-1})_{x=3}$, and *cos* 3 rather than $(cos\ x)_{x=3}$.

With the aid of the symbol j, functions and numerical variables can be separated throughout calculus, just as they have been in (2). In fact, one may, if he so desires, express the results of calculus in the form of relations between functions —the functions themselves, without reference to their values for x or, in fact, to any numerical variable—as in

$$(3)\quad \begin{aligned} D\ sin &= cos, \\ D\ \log &= j^{-1} = 1/j, \\ D\ j^n &= nj^{n-1}. \end{aligned}$$

Similarly, the functions *sec* and *cos* can be related by the formula

$$(4)\quad \begin{aligned} sec &= 1/cos; \text{ that is to say,} \\ sec\ x &= 1/cos\ x \text{ for any} \\ x &= \pm\pi/2,\ \pm 3\pi/2, \cdots. \end{aligned}$$

IV. *The Lack of a Mathematically Usable Definition of Functional Dependence in the Realm of V.Q.'s*

Suppose that all values of the pressure, p, of a gas at 100°C. (written on tags) are collected in one bag, and all values of the volume, v, of a gas at 100°C., in another. The information about p and v contained in the two bags is confined to their ranges and would not permit the inference of a law connecting the two v.q.'s. In fact, Boyle took the domains of p and v into account. He paired acts of manometric and volumetric observations which are simultaneously directed to the same gas sample. He then discovered that for each such pair (γ', γ'')—no matter which sample was observed or when the two simultaneous observations were made—the volume $v(\gamma'')$ was the reciprocal of the pressure $p(\gamma'')$ multiplied by a certain number c (the same number c for all pairs): $v(\gamma'') = c/p(\gamma')$. This fact is expressed in the formula $v = c/p$. Instead, one may also say that, for each of Boyle's pairs (γ', γ''), the pair of corresponding values $(p(\gamma'), v(\gamma''))$ belongs to the function c/j or cj^{-1}, since each of those pairs of numbers is of the form $(x, c/x)$ for some x.

If gas samples of different temperatures are admitted, then there are pairs (γ_1', γ_1'') and (γ_2', γ_2'') of simultaneous observations of the same sample for which $p(\gamma_1') = p(\gamma_2')$ and yet $v(\gamma_1'') \neq v(\gamma_2'')$. This fact is expressed by saying that, without the restriction to gas of the same temperature, the volume is not a function of the pressure.

To physicists, the traditional pairing of acts of observation that are simultaneously directed to the same object has become second nature. But if the domains, A and B, of two variable quantities, u and w, are two classes whatever (not just classes of acts of observation), then no particular pairing of elements of A and B is traditional or natural. Yet, only relative to such a class of pairs (α, β), where α belongs to A and β to B, can the question as to whether w is a function of u be formulated. Such a class of pairs[3] must be given. If for each pair (α, β) of that class the pair of

[3] More precisely, a one-to-one correspondence between a part of A and a part of B.

numerical values $(u(\alpha), w(\beta))$ belongs to the function c/j or *log* or f—that is to say, if $w(\beta) = c/u(\alpha)$ or $w(\beta) = log\ u(\alpha)$ or $w(\beta) = f(u(\alpha))$—then we say that, relative to the given pairing, $w = c/u$ or $w = log\ u$ or $w = f(u)$, respectively.

V. *A Notation That Simulates Non-Existent, and Conceals Existent, Analogies*

The formula $v(\gamma'') = c/p(\gamma')$, for any act γ' of manometric observation (and the simultaneous act γ'' of volumetric observation of the same sample) is analogous to the formula $sec\ x = 1/cos\ x$ for any $x \neq \pm \pi/2, \cdots$. The meaning of the formulae is not changed if we let α (instead of γ') stand for any act of manometric observation, and a (instead of x) for any number $\neq \pm \pi/2, \cdots$. The formula $v = c/p$ relates the v.q.'s themselves without any reference to their values or, in fact, to any arbitrary element of their domains. It thus is analogous to the formula $sec = 1/cos$ relating the functions themselves without any reference to their values. It appears that it is the first half of (4) and the somewhat unusual formulae (3), and not the second half of (4) and the traditional formulae (2), that follow the pattern of the laws of physical science, such as Boyle's law, $v = c/p$.

While the traditional notation conceals this analogy, on the other hand, a comparison of the symbols $sin\ x$ and $f(x)$ with the traditional symbols, $v(p)$ and $w(u)$, for the functions connecting v with p, and w with u, strongly suggests 1) that v and w are of the nature of *sin* and f; 2) that p and u are of the nature of x. In reality, however, v and w are physical v.q.'s, and not functions, whereas *sin* and f are functions; and p and v are physical v.q.'s, and not numerical variables, whereas x is a numerical variable. Thus neither of the suggested analogies is valid.

VI. *The Confusion of Derivatives and Differential Quotients*

If f is a well-behaved function, $\mathbf{D}f$ is another function; e.g., *sin* and *log* have the derivatives *cos* and j^{-1}. If a variable quantity w is a function of a variable quantity u, then usually another v.q. exists, called the rate of change of w with u, which we will denote by the differential quotient dw/du. For instance, the work, W, done in the course of an isothermic compression of a unit volume of gas, is a function of the volume, v, at the end of the process. The rate of change of W with respect to v is a v.q. which turns out to be equal to the pressure p; that is to say, $dW/dv = p$. Any such relation connects three v.q.'s, whereas any formula such as $\mathbf{D}\ log = j^{-1}$ connects two functions. The statement, found in most treatises on calculus, that "derivatives" and "differential quotients" are synonymous terms is thus at variance with the fact that $2 \neq 3$.

The truth is that if a first v.q. is connected with a second v.q. by a function, the rate of change of the first with respect to the second v.q. is a third v.q. connected with the second by the derivative of that function which connects the first v.q. with the second; in symbols, if $w = f(u)$, then $dw/du = \mathbf{D}f(u)$. For instance, the work W done in the isothermic compression turns out to be connected with the volume v by $W = c\ log\ v$. Hence $dW/dv = c/v$ which, by Boyle's law, indeed equals p.

The development[4] of the ideas here presented includes a systematization of the differential as well as the integral calculus, the application of integrals to science, and a theory of functions of several variables.

[4] Cf. the author's "Calculus. A Modern Approach," 2nd ed., Chicago 1953 and the forthcoming book "A New Approach to Mathematical Analysis and Its Applications to Physical Science," Chicago 1955.

The Shortage of Technical Personnel

By W. J. MORELAND

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There is no reason to doubt that the shortage of technical personnel is posing a severe problem for both military and civilian industries—and one that bids fair to continue for several years. But there is reason to believe that the problem itself has not been adequately studied either by industry or by the universities. Even the phrase "shortage of engineers" is so broad as to convey little or no usable meaning. There are research engineers, design engineers, production engineers, etc.; but above all, there is the great range in the degrees of ability of the individuals within each of these categories. Actually, there is probably a greater handicap caused by the misalignment of the men and positions that do exist than that brought about by a shortage of technical people.

It is a curious fact that the selection of manpower to fill vacancies in the sports categories is more scientific and accurate than the selection of manpower for technical positions. For example, a baseball executive never complains that there is a shortage of baseball players. He may complain that there is a shortage of pitchers, but by this he would assume that it is understood that the reference is to twenty-game winners—not just ball players. He is aware of the existence of a sizeable pool of ambitious youngsters anxious to make their mark in the profession. But for him, quality is the important factor—not the total number. Of course, these statements are equally applicable to the problem of the engineering executive. But there is one important difference—in this case there is no simple and accurate measure of the aptitude of the student nor of the proficiency of the graduate. This is especially true in the fields of research and engineering development. Men of mature business judgment will accept the label "graduate engineer" as being a measure of the contents of the package. This, of course, is not the fault of the schools. No reputable institution of learning pretends that the number of years a man remains in school, or the label placed upon him, or even the grades he may earn, is a measure of his ability to achieve success in the technical fields. In fact, the responsibility rests mostly with industry. By offering premiums for labels, they have unwittingly spurred on an increasing number of those poorly fitted to earn these labels. It is the function of the schools and colleges to recognize and cultivate the scientific attitude in its students. But this is an expensive process. It is not being accomplished by today's mass production methods. The schools are aware of this fact but unless more money is made available they cannot hope to supply industry with the people they, in turn, cannot afford to do without.

Sanctuary For Incompetence

A close examination of almost any research organization would reveal a misuse of manpower and a waste of funds. It might seem that such a situation would be a simple matter to discover and correct, but this is not always so. A manager of a development organization of an aircraft company employing several thousand engineers stated that even after six

months employment, it would still be nearly impossible to evaluate the true potential of an individual. No one can pretend to be a ball player, but, unfortunately, it is possible—often unwittingly—to masquerade as a research scientist and perhaps no area in the technical field offers greater sanctuary for incompetence than does research.

At first this may seem paradoxical because of the inherent difficulty of the subject matter and the unquestioned excellence of the people who are leaders in this profession. In the area of research that may reasonably be described as basic, perhaps only 10% of the total effort leads directly to a positive successful conclusion. Nine-tenths of the effort, although perhaps conducted on an equally high level, yields negative results. In one sense this is not wasted effort since it has at least resolved the question of the need for exploration in the particular area. However, it is difficult to distinguish in many cases between incompetence and inherent impossibility of the solution.

A fast growing group of those not well fitted for the task of research is made up of people, usually with excellent academic background, who have become so engrossed in the tools of their trade that they have lost all contact with reality. In this group we might find one who, describing himself as an applied mathematician, could prove, for example, that a bicycle cannot be ridden. When called to his attention that experience was contrary to his conclusion, he is not the least impressed. It is only the beauty and symmetry of his symbolism that is important. He has taken flight from reality. He is a scientific schizophrenic, happy in the world of his own making. Sometimes, in defense of these people, examples are recalled from history which show that great benefits were derived from the apparently aimless meanderings of some earlier genius. This is true. But research is a luxury and it must be purchased with great care. It would be no more logical for an organization to invest a large proportion of its funds in research because of the possibility of great returns than it would for a business man to invest most of his funds in a sweepstakes race merely because it has paid the highest returns on a given investment.

Complicating the problem still further is the existence of another group who have learned that the actions and sounds of competent research people can be readily imitated. They propound ideas and write papers that serve mainly to distract their more competent associates from more useful pursuits. This is strikingly analogous to the example of two locomotives hauling a train of cars. One locomotive may be completely inoperative yet it will look exactly like its mate and perhaps even make the same noises; yet it is riding dead-head, contributing nothing to the effort. It is really impossible from a superficial examination to determine which one is genuine in either case. An erroneous statement made most casually by one such individual may occupy hours of time to disprove. It is a real tribute to the technical stability of this country that it has been able to survive the avalanche of pseudo-scientific papers and reports inspired in many cases by the somewhat frantic efforts of the colleges to maintain favorable publicity ratings.

It would seem to be one function of education to help reduce the magnitude of this problem of misfits by improved selection and training of its recruits. But some phases of modern methods of education are themselves both overly expensive and wasteful. For example, at one engineering school an attempt was made to devise a measure of the efficiency of a lecture. This consisted in defining the efficiency of a lecture as the ratio of the number of man-minutes during which new information was given to the student (which he could not have obtained on his own initiative) to the total number of man-minutes involved during the lecture. Estimates of the efficiency to be expected ranged as high as 75% but the actual results did not exceed 1% for the cases tested.

Suggested Remedy

A suggested remedy for this situation is the elimination of lectures. The teacher could then be used as a consultant to the student but only when the latter needs help and is able *clearly* to state his problem. This is a most revealing method of appraising the student's ability and establishing an atmosphere most favorable for the transmission of ideas from teacher to student. Implied in this approach is the employment of dedicated teachers and few students per teacher. This is expensive. But the added costs would be returned many times in the overall economy. Everyone agrees that in the face of the evergrowing complexity of today's technical problems that industry's pressing need is for greater technical competence. The attempt to supply this need by graduating greater numbers of what must statistically be poorer average quality is even now pressing industry hard. For example, the successful accomplishment of the design, construction and testing of an intercontinental bomber involves the expenditure of many millions of dollars and the best efforts of several thousands of technical people. A director of research at a large aircraft company has stated that he could afford to pay ten times the salary to those who could proceed along beaten paths under their own power until a job was completed as compared to men who required constant supervision in their work; but to the rare individual who could proceed along untried paths with maturity of judgment and persistence of effort to a worthwhile goal, he could afford to pay ten times as much again. Max Börne, the famous German psychologist, has said that in a group of one million men, only one thousand could be described as having done some thinking which leads to logical conclusions, and of this latter group, only one will do original thinking. These examples may be exaggerated, nevertheless, they serve the useful purpose of bringing out in the open a problem that must be faced.

Most everyone is born with some semblance of a research instinct. This is apparent in the relentless questioning with which children approach any new ideas. Unfortunately, some have learned to stifle this instinct so well that long before their college training is over they will accept almost any high-sounding statement or written document without question. A direct result of this unhappy situation is the development of the single characteristic that is fatal to the attainment of the research attitude; namely, a class of individual "who doesn't know that he doesn't know." They have so stifled the still small voice of the questioning instinct that they are able to read a technical statement without being aware that it is not understood by them. Education, which should have the function of cultivating the scientific attitude, often serves instead, like the overwatering of a plant, to anesthetize this instinct.

Mass Production Methods

No one expects the schools to *create* mental giants. All that can be done is recognition, encouragement and some moderate exercising of the important characteristics. In practice, however, our colleges are more concerned with the mass production methods and the setting up of artificial hurdles which, although having some value, can never justify total abandonment of a more logical approach. Not infrequently the student comes away with a sense of accomplishment because of the truly formidable tasks which he has been required to perform in his four to seven years of schooling. Because of this he has mistaken the training routine for the actual battle and when he enters industry it is sometimes a shock to him to find that he is now only at the beginning; that he has picked up a few shiny tools (some of which may be beginning to rust) and that now he must learn the trade. This is the complaint most frequently raised by industry today. This disagreeable situation could be avoided if these facts were to be kept constantly before the student during his training period. Sometimes the argument is advanced that if a school

were to recognize and adopt this completely intellectually honest course, it could not possibly survive in today's strongly competitive atmosphere. But this is merely an abused cliché. There is no evidence to the contrary that with sufficient courage and money, an effort in education that would be a whole order of magnitude better could be accomplished. The following items are suggested as a basis for discussion:

1. Following a common freshman year the distinction should be clearly made between those who wish to follow a truly technical career and those whose concern will be chiefly with man-made problems. No effort should be made to attract men to the advanced technical field by so called "inspirational" talks, financial reward, etc. Rather, the student should be given factual unvarnished information about his chosen field and the true purpose of the training he is receiving.

2. During the second and third years the course content should be common to all the technical students and with no options permitted. The amount of material covered should be reduced to one-half that which it is now pretended to teach and replaced by rigor, thoroughness, and drill in semantics.

3. For the fourth year the student should be permitted to select an *area* of interest but no options within that area.

4. The student would be given the right to earn the degree of research engineer but only *after* completion of a specified time in industry. During this critical period a special effort must be maintained to obtain a measure of his ability. With the maturity of judgment that it is assumed he has now attained, the student should be permitted to select options for his post-graduate work.

Such a program as outlined here, if followed according to the spirit intended, rather than giving mere lip service to it, would be costly and difficult to administer. Whether it is worth the effort should be measured against the contribution it can make toward maintaining economic and military leadership for this country.

Hundreds of men are interviewed daily for positions in the technical field. The process is little more than a ritual. The individual's own opinion of himself, and even his references are notoriously inaccurate technically. Nevertheless, people do get hired and jobs get done. But this may not be enough in an age wherein a few dozen men may solve the problem of pinpointing a hundred of our cities with powerfully destructive guided missiles from a distance of 5000 miles. The men we pick to compete in this contest of high stakes must be the top dozens. Only a few misfits and the results could be fatal. The same reasoning applies, only with lesser force, in our commercial economy. As technical advances become more profound and fewer men are involved, it becomes proportionately more important that those selected be really qualified. Offering high salaries is no easy out since it merely invites competition between the man of words and the man of deeds in a contest whose rules, as most commonly applied, favor the former. Like, for example, picking the best mile runners by insisting they swim the distance.

Characteristic Qualities

Qualities characteristic of successful research people are (1) intellectual courage; a kind of boldness in thinking but not recklessness; (2) the peculiar ability for sustained mental concentration; in effect, mental experimentation. This factor is not entirely subordinate to the will, hence, cannot be demonstrated at will. It responds under favorable environment and gains momentum after mental probing reveals a likely path of attack on a problem; (3) the ability to translate the essential factors of a physical phenomenon into mathematical language. This must not be confused with skill in mathematical manipulation. Mathematics is only a tool. The mental process of the scientist may be likened to the coarse adjustment of a microscope. It feels its way probing a whole area for study, while the mathematical tool, like the microscope vernier,

serves to sharpen the field of view. There is little more reason to assume that a mathematician should have this ability than to assume that a chauffeur could design an automobile; (4) the ability—most difficult to achieve—to maintain a proper balance of effort between the several phases of a project. For example, when theory leads to an impasse, then an appeal is made to experiment and vice versa. Knowing when to advance, and when to retreat from an untenable position, husbanding resources and maintaining interest until a useful conclusion is reached is a most valuable asset. None of these qualities can be revealed by superficial tests or interviews.

The solution of the problem of assigning men to the research job for which they may be best suited holds so much promise of reward that time and effort would be well spent on its study. Two steps are suggested: (a) the accumulation of accurate descriptions of the achievements of the individual insofar as they pertain to qualities similar to those outlined above—not daily activity reports; (b) the evaluation of these records by competent and interested leaders. To be successful, such a program must have the full cooperation and sympathy of the individual. He should be prepared by preliminary indoctrination for the unnatural procedure of attempting to be completely frank and unbiased in his judgment of himself. To help bring this situation about he must be shown that he stands to gain both in mental satisfaction and standing in his profession by his cooperation in the program.

As remarked at the beginning, there is a shortage of engineers; but, as engineering executives know, the talent that is available is our most ineffectively used resource. Here is a promising field of study which can yield important returns to the security and economy of this country.

Graduation, Hold-Back, and Withdrawal Rates in Engineering Colleges

By A. PEMBERTON JOHNSON *

Project Director, Engineering Tests, Educational Testing Service

Introduction

Recently graduation, hold-back and withdrawal rates were compiled and analyzed for over 13,000 fall-of-1948 freshman entrants to 101 engineering colleges. The complete findings of this study, carried out for the U. S. Coast Guard by Educational Testing Service (ETS), Princeton, New Jersey, were reported during May 1953 to the participating engineering colleges by Headquarters, U. S. Coast Guard in an ETS Statistical Report entitled, *Four Year Follow-Up Study of 1948 Freshman Entrants to Engineering Colleges.* This report is now out-of-print. A brief summary of its findings was reported by Dr. Henry H. Armsby in the November 1953 issue of *Higher Education* (published by the U. S. Department of Health, Education, and Welfare) under the title, *Graduation and Withdrawal Ratios.* The present article is intended to provide a summary of this study's findings for those engineering educators who have not seen the earlier publications, and to provide certain interesting comparison data.

Origin of the Study

The program of the U. S. Coast Guard Academy (accredited by ECPD as an engineering-general curriculum) is under constant study by an Advisory Committee of non-service personnel. To provide a factual basis for answering congressional questions regarding the attrition rate at the Coast Guard Academy, the Advisory Committee inquired carefully about recently published data in comparable civilian engineering schools. Finding data of this kind to be completely lacking (and knowing that such a study would be helpful not only to the Congress, the Coast Guard Headquarters, the Advisory Committee, and to the Coast Guard Academy but to engineering education generally), The Commandant, U. S. Coast Guard arranged that the study be undertaken.

Outline of the Study

This is a study of the graduation, hold-back, withdrawal or drop-out of *individual* students. It deals with the first post-war entering class to be primarily non-veterans [1] and is limited to *male non-vet-*

* The author acknowledges with deep gratitude his debt to the following persons whose efforts made possible this article and the study upon which it is based: (1) The Commandant, U. S. Coast Guard, and Dr. Joseph W. Barker, Chairman of the Advisory Committee of the U. S. Coast Guard Academy; (2) The engineering administrators, the registrars and their staffs who painstakingly compiled the data for their institutions; and (3) The ETS staff, particularly Dr. Marjorie Olsen and Dr. William B. Schrader. Professor Bronwell's kindness in suggesting this article is greatly appreciated, as is Dr. Armsby's kindness in allowing this author to quote liberally from his November 1953 *Higher Education* article.

[1] The February 1949 JOURNAL OF ENGINEERING EDUCATION shows 47,426 male students and 14,900 male veterans enrolled as freshmen in U. S. engineering schools and undergraduate extension centers as of November 1, 1948. The proportion of non-veterans is therefore 47,426 – 14,900 divided by 47,426 or 68.6%.

erans. It does not include students enrolled in cooperative programs which alternate periods of college study and industrial work. It includes no transfer students. In the fall of 1952, each of 185 undergraduate engineering colleges (substantially all U. S. engineering colleges) were asked to complete a carefully pre-tested questionnaire. This form requested summary *four year follow-up data* through July 15, 1952 for all male non-veteran engineering college freshmen who had entered each institution in the fall of 1948, prior to November 1.

By mid-winter 1953, 101 engineering colleges had furnished virtually complete and usable data for over 13,000 entrants. These data enabled classification of institutions and their graduation, hold-back and withdrawal rates by size, institutional type, and geographical region. On these three bases, the 101 institutions provide a good, though not perfect, cross-section of United States engineering colleges. It is difficult to know in what respect and to what degree the findings of this report might differ, if data had been included for those institutions which did not return a completed questionnaire.

The Principal Findings

For the 101 colleges, the principal findings are:

1. *One-third* (i.e., 33% of the entrants graduated in four years from engineering or had completed satisfactorily four years of a five-year program of study.

2. 11% of the entrants were still enrolled. (It is estimated that most of these graduated by June 1953.)

3. More than *one-half* (i.e., 56%) had withdrawn or been dropped from engineering during the four years. Of their entrants who withdrew or were dropped, the colleges reported that nearly half were failing or had failed academically, but that two out of every five had withdrawn in good academic standing. In this connection may be quoted a reply by one college official to the request for data: "A large number of students who either are dropped from engineering or who find the program too rigorous are permitted to transfer to our Liberal Arts College or our School of Business, and many of them are accordingly salvaged and receive college degrees in these other areas."

4. Almost *half* (i.e., 46%) of entrants to *privately-supported* colleges graduated in engineering at the end of four years, while only one-fourth (i.e., 25%) of entrants to *publicly supported* colleges graduated in engineering in four years.

5. About *two-fifths* (i.e., 41%) of entrants to *technological institutions* graduated in engineering in four years, while over *one-fourth* (i.e., 27%) of entrants to universities graduated in engineering in four years.

6. Graduation rates differ geographically. In the South Central States (Arkansas, Louisiana, New Mexico, Oklahoma, Texas) less than one-fifth (i.e., 18%) of the entrants graduated in four years while about one-half (i.e., 47%) of entrants in the Northeast States (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and New York, except Metropolitan New York City) graduated in four years.

7. Graduation rates among the 50 largest engineering colleges reporting data on 100 or more entrants differ more widely between colleges (ranging from 62% to 9%) than between regions or between institutions of different types or of different numbers of male non-veteran entrants.

Comparisons with Other Disciplines

The most recent comprehensive study of graduation and withdrawal rates for individual students in several disciplines appears to be that reported by the Office of Education in Bulletin 1937, No. 11, *College Student Mortality.* In referring to this in his November 1953 *Higher Education article,* Dr. Armsby states:

> The Office study covered students who entered college during the academic year 1931–32 in a group of 25 cooperating institutions. It included 2,547 students in 16 engineering colleges. . . . The 1937 bulletin reported 30 percent of engineering students graduated in 4 years and 62 percent dropped or with-

drawn. Corresponding figures for other disciplines were: Arts and science, 29 percent and 67 percent; commerce and business, 24 percent and 67 percent; home economics, 31 percent and 65 percent; agriculture, 34 percent and 60 percent; and education, 42 percent and 53 percent.

In his discussion Dr. Armsby says:

The statement is often made that the "student mortality" in engineering schools is unduly high, generally with at least an implication that it is much higher than in other disciplines. The earlier study mentioned above indicated that for the class of 1935 the mortality rate was lower in engineering than in 3 of the other 5 disciplines studied, and lower than the weighted average of the 6 disciplines covered. The ETS study shows a lower mortality rate for engineering students for the class of 1952 than for the class of 1935. Unfortunately comparable figures for the other disciplines are not available, but it seems likely that the engineering schools are graduating at least as many of their entering students in 4 years as are schools in most other disciplines to which students are admitted upon graduation from high school.

It is practically certain that improved programs of selection and counseling in junior and senior high schools and in colleges and universities, better teaching at all levels, and more ample financial assistance for needy students, could materially reduce "student mortality" in *all* disciplines.

Comparison with Earlier Studies

Although the differences below may largely reflect chance variations, the findings of this study are slightly more favorable than the findings of two earlier studies: (1) that of the Office of Education for 1931 entrants; and (2) that of the Wickenden *Report of the Investigation of Engineering Education 1923-1929* [2] for the classes of 1923 and 1924.

Classes entering in the fall of	4-year graduation rate (%)	4-year hold-back rate (%)	4-year withdrawal rate (%)
1919–1920	28	10.4	61.6
1931	30	8.0	62.0
1948	33	11.0	56.0

Findings for Hold-backs

Of those who were then enrolled but did not graduate in four years, 62% were reported to have been held back because of academic deficiency, 4% for illness and the remainder (34%) for other unspecified reasons. Colleges with 300 or more non-veteran entrants, private technological institutions, colleges of arts and sciences and colleges in the Northeast reported distinctly higher than average percentages of non-graduates held back for academic deficiency. Colleges in the West North Central states (Colorado, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wyoming) and Western states (Arizona, California, Idaho, Montana, Nevada, Oregon, Utah, and Washington) reported distinctly lower than average percentages of non-graduates held back for academic reasons.

Remarks made on the questionnaires suggest that the principal reason for hold-back may often be hard to determine, and that therefore the reported reasons may not dependably reflect the actual reasons.

Findings for Withdrawals

Among the 50 largest engineering institutions the percentage of students who had withdrawn or been dropped ranged from 29 per cent to 75 per cent. Averages, weighted according to numbers of students were: all 101 engineering colleges in the study, 56 per cent; 53 colleges in universities, 60 per cent; 30 separate engineering colleges, 48 per cent; 50 public institutions, 62 per cent; 33 private institutions, 45 per cent.

An appreciable proportion of the graduates of the 50 largest institutions had experienced academic difficulties: 26 per cent of them had at some time repeated

[2] Volume I, p. 200, of Two Volumes, published by the Society for the Promotion of Engineering Education in 1930 (Vol. I) and 1934 (Vol. II).

one or more courses, 11 per cent had attended one or more summer sessions, and 12 per cent had been on probation for one or more terms. Here again there were wide variations among individual institutions, reflecting, in part, ways of defining and categorizing academic difficulties, and of record-keeping. The percentage of graduates of the 50 largest colleges who had repeated one or more courses ranged from 0 to 71 per cent. Those who had attended one or more summer sessions ranged from 0 to 56 per cent, while those who had been on probation for one or more terms ranged from 0 to 33 per cent.

More than half (57%) of all withdrawals occurred during or by the end of the first year of college, the figures being 27 per cent during the first year and 30 per cent at the end of the year. The withdrawals during or at the end of the second year amounted to 28 per cent of all withdrawals, during or at the end of the third year 11 per cent, and during the fourth year 4 per cent. Considering the withdrawals in terms of percentages of entrants shows that 32 per cent of all freshman entrants were dropped or withdrew by the end of the first year, an additional 16 per cent during or at the end of the second year, another 6 per cent during or at the end of the third year, and 2 per cent during the fourth year—a total of 56 per cent.

Of those who withdrew or were dropped 25.4 per cent were dropped by the college, and 21.5 per cent withdrew voluntarily, but "in failure standing." However, the study contains a note of caution concerning the distribution of withdrawals and the distinction between failing and good standing. Considerable variation was found in the reporting practice in different institutions, and 12.1 per cent of all withdrawals were reported as either "other reasons" or "unknown standing." It was pointed out by many of the colleges that it was difficult for the college to know the reasons for many of the withdrawals.

Of all voluntary withdrawals from engineering: nearly one-half (46%) were made to effect changes in curriculums, and of these more than half (28% of all withdrawals) were students in good academic standing. Only 7 per cent were reported as having withdrawn for financial or family reasons and only 6 per cent because of dislike of engineering. The remaining 41 per cent of the voluntary withdrawals were for various reasons, including military service, transfers to engineering in other institutions, and academic difficulties.

Reasons for the Variations Found

This study did not attempt to pinpoint the reasons for the wide variations in graduation and withdrawal rates among institutions. Carefully conducted studies by appropriate staff groups of individual institutions might in many instances discover circumstances susceptible of improvement along with other circumstances probably not readily alterable by the institution.

Engineering Education Across the Country*

By DEFOREST L. TRAUTMAN

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In this period of evaluation, stimulated in its concerted form by the American Society for Engineering Education, the author was tempted to look about at the present overall enterprise of engineering education. Fortunately, he was enabled to yield to his temptation [1] and spent a year visiting other colleges in the country. These visits provided opportunity for living with students, sampling classes, speaking with staff and administrators, and reading unpublished literature relative to educational planning. The remarks of this paper are the result of his experience and comprise four overall, composite observations of present practices, trends and problems. From these stem suggestions for stimulating the coherent development of engineering education.

Although the questions posed of the educational enterprise continue to be the same down through the ages, the answers expected of engineering education are now more insistent than ever before. The following statements are made poignant deliberately to arouse interest and thus encourage these hoped-for answers.

Observations

1. *It appears that the nature of engineering education is almost everywhere the same—training for routine doing.*

This consists of preparing students during a limited period for immediate entrance into a career occupation reasonably well defined according to industry and function. Such preparation can be primarily training, and both curriculum and instruction tend to emphasize the practical. Curricula are oriented toward subject matter, and instruction is dictated by the text book as throttled by the instructor. Problem assignments and laboratory experiences are composed around specific apparatus and established procedures. These practices tend to emphasize routine doing rather than creative knowing, and this doing is restricted to the solution of problems already formulated and/or requiring no decision at their inception or conclusion.

Working objectives depend upon what is deemed important relative to facts, concepts, method and/or disciplines. The specific nature of the educational program found at a given school depends not only on overall goal and objectives but also on the character of the institution, students, staff, and administrative leadership. It is not common to find aggressive educational leadership and a staff working together to achieve a common objective.

The two publicized facets of the modern trend are (a) emphasis on the engineering sciences and mathematics and (b) attention to socio-humanistic studies. The former has given rise to departments of engineering science, and an increased attention to research and graduate study. Some persons believe the essence of engineering to be science and mathematics, and they predict that departments devoted (exclusively) to such are the only ones to survive. Regardless of the emphasis on science, such material is generally viewed as a tool. Engineering art is not emphasized as such but may be

* Presented before the Pacific Southwest section of ASEE, San Jose, California, December 29, 1953, and before the Educational Methods Division, ASEE Annual Meeting, Univ. of Illinois, June 17, 1954.

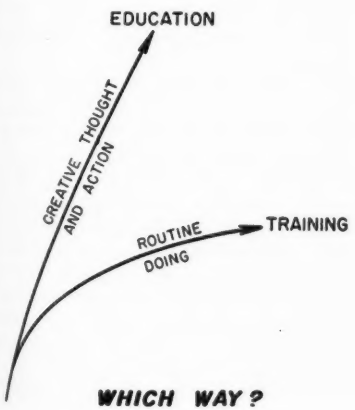
[1] Through the generosity of the Fund for the Advancement of Education (Ford Foundation).

present in information, application, or (traditional) design courses. Despite the heralded design (or synthesis) hallmark of engineering, the undergraduate program is almost exclusively analysis.

The attention to socio-humanistic studies has been part of the movement toward gaining recognition of engineering as a profession. Although some 15% timewise is devoted to a smorgasbord or an integrated program, no one is prepared to evaluate the outcomes. Such subjects are generally believed by the staff to be necessary despite the overwhelming feeling of the students to the contrary. Very soon after their arrival on campus students acquire (no one knows quite how) the set of stereotyped attitudes which helps stabilize the nature of engineering education stated above. The general public is not informed of any departures, even where extensive ones exist.

2. *Potentialities of the student as a learner or as a creative individual in general are not exploited.*

Of major interest to the educational experimentalist is that students appear to respond to their treatment the same regardless of school. They will generally attempt to do what is assigned regardless of the rigor of approach as judged by standards elsewhere, because they "know no different." Nevertheless, the authoritarian character of the subject matter and of the instruction is such that the student must display the accepted approach to get the accepted answer to standardized types of questions.



Moreover, the instructor is inclined to rank the difficulty of an approach in terms of how recently (or how well) he has learned it, forgetting that to the student *all* approaches are equally new (e.g., what appears to the teacher as a graduate approach may work wonderfully with sophomores).

Although classes are usually small (under 35) class time is given over primarily to lecture. The emphasis on subject matter coverage minimizes use of recitation and discussion techniques (despite a natural free-time tendency of mankind toward "bullsessions"). Students scarcely have the time to do the required work, and have not the leisure of their colleagues in other departments of the University.

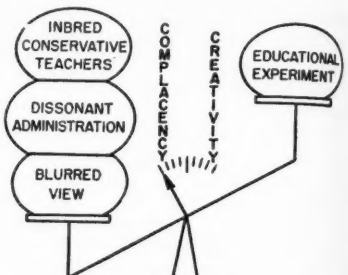
No concerted attention is given the gifted student (or even those above average), as found through Honors Programs in some other college of the University, or through the complete freedom found in some European Science education. Mores are set by a strict grading system.

Students select whole curricula, rather than courses, disciplines or teachers. The prevalent subject matter department and option schemes, originally planned (in part) to capitalize on student interests, now find their influence on student motivation waning.

Some schools have recognized these prevalent forces, and have begun to help the student acquire (or at least not lose) a more flexible outlook and to provide him the opportunity of carrying out his desires. In many schools the totality of the activities of the student is thus beginning to receive attention, and advising programs are being established. Consideration is given to the working conditions of the student, his dorm life, his co-

curricular activities, and what *he* actually does in the classroom.

3. *The vigorous evolution of engineering education is hampered by:*
   - *A. Complacent, inbred and conservative teachers,*
   - *B. Dissonant administrative framework, and*
   - *C. A blurred view of the essence of engineering education.*



Complacency results in a lack of desire for change, and is considered the chief enemy of progress. Unfortunately it is rather widespread, prevailing chiefly among those who have lost contact with the profession of engineering, and/or who have found it possible to peddle the same line continuously.

The engineering teacher is also inbred and conservative. Although inbreeding can be the pattern in all vocations (because of the old training the young, etc.), it is certainly true in engineering. Furthermore, the engineering profession today is so rapidly changing that the teaching habits of yesterday are not sufficient for tomorrow. Conservatism stems in part from the nature of the academic system in which the staff is individualistic and in which counsel is sought only from the peers—the resourcefulness of the younger persons is left untapped. Some ten to twenty years later when the younger persons have become peers many of the former ideas—now conservative—will be taken off the shelf.

The administrative framework of many engineering schools is not consonant with satisfaction of student choice and expanding knowledge. Traditional departmentalization, based on training for industry, has produced almost inpenetrable blocks of vested interest, causing departmental rivalries, duplication of course offerings and laboratory facilities, competition in the now evolving common areas of professional activity, and the *accursed* service course. The fact that so many openings for deans of large engineering schools exist for so long a time is partial indication of lack of educational leadership. This condition is unfortunate at a time when engineering education is being reevaluated with such national and local interest. Daring, resourceful, qualified educational leadership is sorely needed.

The key theoretical objective of higher education is generalization of knowledge. This should lead to instruction centered on causing the student to learn concepts (or principles) rather than facts, and such is the result of integration of knowledge. Such integration can proceed on a basis of content or method. The bounds of engineering appear to some to be receding sufficiently to permit further subdivision of programs offered, either on a basis of industry or function. The opposing force is one of unification, that of recasting the emphasis toward essential disciplines underlying both industry and function.

However, the essential essence of engineering education has not been crystallized. This has lead to real or apparent problems of accreditation and a suggestion for bifurcation. Persons are not certain what does characterize engineering or engineering education but appear to be influenced most by new advances in technology or a cleavage of function. (This increase in subject matter leads some to frustration.) Some recognition is being given the relative role of facts, concepts and disciplines as related to education both for function and industry.

4. *Despite the general complacency educational experimentation does exist.*

In each school there are individuals who are trying something different. Often this is the fruit of introspection stimulated nationally by the ASEE and/or locally as a result of administrative changes or industrial pressures.

Each school or department has its own set of working objectives, either explicit or implied, and "activities elsewhere" may thus provide stimulation, suggestion and/or actual data. The following are cited because of their uncommonness, and as evidence of the kinds of departure being effected.[2]

a. Concentration of engineering subjects in the upper division. This stems from the spread of the community college and junior college pattern, the financial necessity to minimize and unify the lower division engineering offerings, and the evolving nature of engineering as an upper division—graduate discipline based on a broad foundation of science, mathematics and socio-humanistic studies.

b. Pre-junior summer engineering camp for all engineers to unify their lower division work. A community survey project helps the student to integrate his prior socio-humanistic and technical knowledge, and also to evolve ideas relative to the role of engineering in modern society—an experience especially of value to students coming to the campus as Juniors.

c. Continual modernization of subject matter content, through research and scholarship.

d. Elementary and advanced sections of same or similar course meeting together —a version of the one-room schoolhouse.

e. Integrated lower division math-physics course (with remarkable results).

f. Interdepartmental disciplines in instrumentation, nuclear science, materials, system analysis and engineering science (where it is not a separate department).

g. Integration of all courses both within and outside engineering around the theme of a common (scientific) methodology. Gives students confidence and power in meeting new situations.

h. High school graduation not required. Good early entrants (after tenth grade) do well in engineering. Other programs also minimize redundancy of 11–14 grades.

i. Student questions "answered" by questions from instructor—guide student to evolution of his own answer and more personal knowledge about the knowing process. Great teacher success also claimed when student is caused to relate the subject matter (whatever it may be) to his own personal problems.

j. Evaluation situations directly related to objectives. Examinations prepared by special group. Take-home exams worked with collaboration—even with instructor. Senior comprehensive in engineering.

k. Acceptable industrial employment required for graduation (usually one summer). Engineering practice school post B.S.

l. No departmental subdivisions; all staff members contribute to and are serviced by the main stockpile of ideas and concepts; students satisfy their specialized wants through technology course selectives in the senior year.

m. Unified laboratory (rather than with separate courses). Knowledge from all courses must be brought to bear on given laboratory situations.

n. Accreditation not sought for four year program.[3]

o. Proceeding via course exams at student pace.

p. Birth of programs such as Pharmaceutical Engineering to prepare engineers for specific industry unattractive to "conventional" engineers (or more demanding).

Suggestions

Consideration of the possible implications of these observations has led the

[2] The author will refer queries from interested readers to the pertinent persons and/or schools.

[3] There exists no strong force toward lengthening of the undergraduate program although no coherent educational analysis has been advanced.

author to propose the following four-fold manner in which the coherent and effective development of engineering education might be stimulated. These are not answers but rather directions in which to pursue answers.

1. *It is important—isn't it?—to understand the nature of engineering when planning programs in engineering education.*

The schools serve the dual purpose of preparing persons both to *practice* the profession and to *lead* the profession. Engineering education is thus both the follower and the forerunner of engineering, and they therefore must evolve together.

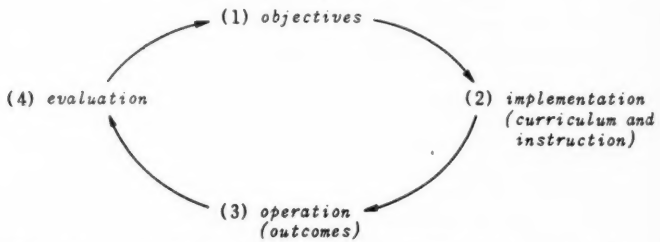
In getting a handhold on the nature of practice and of education it appears profitable to strip off adjective multipliers (by industry or function) and emphasize the key word itself—engineering. Our educational goal is to enable the student to develop the requisite disciplines for a foundation for professional activity in a limited period of time. These, if in the category of thinking, knowing, communicating (etc.), are relatively independent of the subject matter employed. People, however, are not yet agreed as to what the body of engineering knowledge is nor what the fundamental things to be taught are.

2. *Should we not be keenly aware of educational activities outside of engineering?*

The suggestion to look without engineering need not imply that other enterprises are more successful than is engineering education, but rather that through sharing points of view, by contrast, significant points are driven home. We might be interested to observe architecture, medicine and business, and integrated programs in general education.[4] Several non-engineering faculties have already rallied round a cause sufficiently to provide significant data. Much may be gained through thoughtful consideration of the socio-humanistic studies. The author has also found helpful the educational approach of certain industries.

3. *We have excellent examples of a decided element of objectivity in the functioning of successful engineering enterprises.*

Engineering education should be no different from other human endeavors in which the following four facets are effectively related



[4] The Foundation for Integrated Education (New York) purports to be a clearing house for ideas and inspiration.

with a functional relation implied between them, and the last leading back to the first. This scheme permits treatment of problems in education by the same methodology as problems in science, employing a measure of analytics and a measure of experience. In the realm of providing such an educational rationale there exists the possibility of distilling out what might be called a science of education, whether it pertains to curriculum or to instruction. (That portion which appears to be the traditional art can then receive appropriate emphasis.) The rationale would also likely include a discovery of the basic requisite disciplines necessary to the utilization of knowledge.[5] All told, these activities might be grouped under the heading of *Education Engineering.*

4. *A formal educational background is considered practically indispensable to the preparation of future engineers. Might not this concept apply to future educational leaders as well?*

Such definitive attention to the development of our future educational leaders might encompass study in the three areas mentioned above: Nature of engineering, non-engineering experiences and educational rationale. The men produced solely by the enterprise of engineering education tend to be more oriented toward getting the job done than to consideration of longer range philosophical issues. Attention to the latter appears to be a necessary requisite of able educational leadership in a technological society.

[5] Possibly in contrast to the extension of knowledge.

ANNUAL MEETING—1955

Pennsylvania State University

State College, Pa.

June 20-24, 1955

"YETs? What's That?"

By ROBERT T. HOWE

Asst. Prof. of Civil Engineering, University of Cincinnati, and Chairman, 1953-54, Committee on Young Engineering Teachers

The Committee on Young Engineering Teachers has been a part of ASEE for four years. Almost everyone who has attended a Sectional, or National Meeting during this time has heard of the Committee, and many have attended YET sessions at these gatherings. Older members often say they wish that YETs had been in existence when they were younger. Never-the-less there are Society members, including a great many younger ones, who say "YETs? What's that?". This article will attempt to outline the role of the Committee on Young Engineering Teachers in Society affairs.

History of the Committee

After a year of studying how ASEE might be of greater service to its younger members, and also develop future leadership for its activities, a committee headed by Professor Frank L. Schwarz submitted a report to General Council. This report, published in the April 1950 issue of the JOURNAL OF ENGINEERING EDUCATION, recommended that a Committee on Young Engineering Teachers be formed within the Society, and suggested the following objectives for such a group:

1. An understanding of the general goals and responsibilities of the two professions which every teacher of engineering follows, engineering and education.
2. Orientation into the history, the lore, and the "unwritten laws" of the dual profession of engineering education.
3. An acquaintance with the most effective instructional materials and methods, with methods of evaluating student achievement, and with the elements of counseling and student guidance.
4. Guidance in his personal professional development both as an engineer and as a teacher.
5. A means of exchanging ideas with his contemporaries.
6. Stimulation.
7. Dissemination of knowledge.

Such a Committee was formed during the 1950 Annual Meeting, and it has grown in size and activity yearly since that time.

The suggested objectives, quoted above, have met with widespread approval within the Committee. While they have never been officially adopted, they have been "absorbed" as the goals of YETs. During the past four years YETs have considered two themes based upon these objectives: "Teaching Experience vs. Research vs. Industrial Experience vs. Ph.D. As the Road to Good Teaching," and "The Professional Development of the Young Engineering Teacher." These topics have provoked a great deal of discussion which has helped young teachers to formulate their personal plans for becoming true engineering educators.

The original study committee suggested that "young" be defined as "not over 36 years of age, and of rank below associate professor." This definition caused the Committee so much embarrassment during the first two years of its existence that at the 1952 Annual Meeting the Committee decided to abandon all formal definitions of "young" in regard to those who might participate in YET activities, but to re-

tain the definition, in so far as possible, in the selection of Committee Officers, and further, that the Chairman should always meet the suggested restrictions.

Purpose of the Committee

A strange paradox exists in regard to reactions to the existence of this Committee. Older members almost unanimously comment on the great value of such an organization and often say, "We wish that there had been such a group when we were younger.", while young teachers often say, "Why should be belong to such a special group? We want to be accepted as full members of the Society!". These two reactions seem to distinguish between those who know why the Committee exists, and those to whom this article is directed.

The Committee on Young Engineering Teachers might be compared to a seed bed into which the Society scatters all kinds of seeds in the form of its new, young members. Each seed has the potential ability to grow into a worthwhile plant, so each young member has the potential to develop into an outstanding teacher, a research scientist, a counselor of students, an administrator, or as a hybrid of two or more of these types. The Society waters and fertilizes this seed bed with encouragement, and moral and material assistance, looking forward to the day when each seed will blossom forth as an engineering educator.

Just as seeds must sprout both roots for stability and leaves, stems, and flowers or fruit for beauty and utility, so the young teacher must grow both in wisdom and in stature. He must send out roots seeking for new knowledge, or new means of communicating knowledge, and he must simultaneously show forth this new knowledge in productive activity. Some seeds try to grow bigger within their own skins and never burst forth into usefulness; others send out inadequate roots so that the bloom which comes quickly also fades quickly; while still others develop extensive root systems, but are gnarled and distorted above the ground. Similarly some young teachers are so concerned with making money that they neither study nor grow in usefulness; others want to be seen and heard but are unwilling to attain the knowledge which makes their actions worthwhile; while still others become so engrossed in acquiring knowledge that they never take time to effectively transmit that knowledge to others.

A seed may be planted and cared for but it cannot be made to sprout, for the power to grow lies within the seed itself. Here men have one advantage over seeds for while each man can develop personally and professionally only as he desires to develop, fellowmen can help and encourage each other in the growth process, if only by inciting competition to attain a desirable goal. Here then is the purpose of the Committee on Young Engineering Teachers; it is an organization directed toward encouraging young engineering teachers to develop into well-rounded engineering educators. As the objectives quoted above indicate, YETs are concerned with helping embryo teachers develop both roots of understanding and stalks of fruitful activity.

Because seeds are often sown too densely in a seed bed the gardener transplants the stronger sprouts to other areas so that they may continue to grow individually while the seedlings left behind have more room in which to show forth their value. As young ASEE members develop on their local campuses they are observed by YET Subchairmen who nominate them for greater responsibilities within the Committee. As the Subchairmen grow in ability they are transplanted into Section, Division, or higher YET Offices by the Society Officers who are observing their work. In this way room is constantly being prepared both for new young members to become active, and for established young leaders to continue to grow in usefulness.

Conclusions

Society members who know of the purpose of this Committee look upon it as a

seed bed. If you are a new, young teacher what kind of a seed are you? What kind of an engineering educator do you hope to become? If you are anxious to grow in usefulness the Committee on Young Engineering Teachers will welcome you into its activities of mutual encouragement and help toward personal and professional growth.

If you want specific information about YETs why not write today to Professor Philip Weinberg, Department of Electrical Engineering, University of Utah, the Chairman of the Committee for 1954-55?

Sections and Branches

After accepting the invitation to hold a fall meeting of the **ASEE–Ohio Section** at the USAFIT, Wright-Patterson Air Force Base, Ohio, a two-day conference was decided upon to permit the visitation of the Base laboratories, the inspection of the physical equipment of the Air Force Institute, and the viewing of the latest aircraft, in addition to the holding of a technical session.

R. A. Seaton, Director, USAFIT, welcomed the visiting delegates to the Wright-Patterson Air Force Base, Ohio. General Swofford, Commandant of the Institute, was away on official orders on an assignment in California.

The first paper presented treated the "Geopolitic Significance of Indo-China and Brazil in Relation to the Rubber Industry." A. L. Freelander, President, Dayton Rubber Company, was well qualified to speak on this topic due to his association of long standing with the rubber industry.

In his paper, "Titanium, Its Current Engineering Status," Lt. Harris M. Burte, Project Engineer, Light-Metals Section, Materials Laboratory, WADC, discussed the processing, the fabrication, and the applications of this light metal in present day practice.

Chairman K. F. Sibila, University of Akron, presided at the 1800 hour dinner meeting, and introduced President N. W. Dougherty, ASEE, University of Tennessee, who addressed the group on the topic of "Engineering Education."

The evening entertainment consisted in the viewing of two base films, the one depicting the life of a stranded plane crew in the tundra of Alaska after a crash landing; the other showed the reactions of the two white mice and the two monkeys as they were subjected to gravitationless status in the rocket that soared 240 miles into outer space above the sands of New Mexico a couple of years ago.

The first part of the second day's program consisted in inspecting the facilities of the Base Technical Institute to impart an engineering education. Exhibits were on display and experimental demonstrations were given in the following departments: Electrical Engineering, Aeronautical Engineering, Mechanical Engineering, Installations Engineering, Mechanics, Physics, and Industrial Administration. The Institute's Library was open for inspection. Military and civilian staff members were in attendance to demonstrate experimental set-ups and to answer questions raised by the visitors.

The conference closed with the tour of the flight lines of Area A and Area B of the base where the latest types of Air Force aircraft could be seen.

A Brief Report on the Salaries of Engineering Teachers Based Upon Data Collected by Engineers Joint Council in 1953

By FREDERICK R. HENDERSON

Associate Professor of Industrial Engineering, Northeastern University

Foreword

In June, 1949, the A.S.E.E. Committee on Faculty Salaries published "A Survey of Teachers' Salaries in Engineering Schools and a Comparison of These with Salaries Paid to Engineers in Non-Teaching Employment and with Teachers' Salaries in Other Professional Schools." Included were data from 123 engineering schools covering salaries of 8541 members of their teaching staffs for the school year 1948–49.

In April, 1953, the Engineers Joint Council, as part of a survey of earnings of engineering graduates, sent, to the deans of all engineering schools, questionnaires to be answered and returned to E.J.C. by individual faculty members. Approximately 3000 of these were returned, and after they were analyzed by E.J.C., these questionnaires were turned over to A.S.E.E. for such further analysis as the Society wished to undertake by way of supplementing the 1949 A.S.E.E. salary survey.

A preliminary study of the E.J.C. questionnaires immediately revealed a substantial variation from the 1949 A.S.E.E. study insofar as the distribution by geographical region and professorial rank was concerned. The Executive Board of A.S.E.E., therefore, concluded that any detailed comparison between the 1949 data and the E.J.C. questionnaires was not feasible. It did appear, however, that some general conclusions as to trends could be drawn, and at the request of the Executive Board, Professor Frederick R. Henderson of Northeastern University agreed to make an abridged study of the E.J.C. questionnaires and to prepare a brief report on the results obtained for the A.S.E.E. Annual Meeting in June, 1954.

Grateful acknowledgment is made to Mr. W. T. Cavanaugh, Assistant Executive Secretary of the Engineering Manpower Commission of E.J.C., for his cooperation in making available the questionnaires upon which this report is based and to Dean Wilfred S. Lake of Northeastern University for his friendly counsel in matters of statistical procedure.

Purpose and Plan of the Report

Introduction

Having examined the salary questionnaires submitted to E.C.J. by engineering faculty members in the spring of 1953 to determine first of all whether or not these constituted a sufficiently representative sample to warrant further statistical analysis, and having reached the conclusion, with certain minor reservations, that the sample was in the main adequate for this purpose, I have endeavored to answer the following questions.

1. What significant changes have occurred in faculty salaries from 1948 to 1952?

2. What was the financial situation of engineering teachers in 1952–53 as compared with their classmates in industry and government?
3. What is the relationship, if any, between the so-called base salary for teaching during the academic year (9–10 months) and the total earned income for the calendar year?

Treatment of the Data

Since the 1949 A.S.E.E. survey reported salaries on a 10-month basis (12-month salaries having been reduced by 1/6), the same basis was adopted for the "basic salary" on the E.J.C. questionnaire, and basic salaries covering 11 or 12 months were reduced 1/6 before tabulating them.

The A.S.E.E. survey included only the four ranks of professor, associate professor, assistant professor, and instructor. It, therefore, seemed wise to disregard E.J.C. questionnaires from deans and from persons engaged wholly on research.

A few questionnaires from areas outside the continental United States were also eliminated since these areas were not included in the previous study.

The A.S.E.E. survey divided the country geographically into seven regions, and the same division was adopted for this study. These regions are as follows:

Region I. Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut
Region II. New York, New Jersey, Pennsylvania, Delaware, Maryland
Region III. Ohio, Indiana, Michigan, Illinois, Wisconsin, Iowa, Minnesota
Region IV. Virginia, District of Columbia, West Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi
Region V. Missouri, Arkansas, Kansas, Oklahoma, Louisiana, Texas (East of Pecos River)
Region VI. California, Nevada, Utah, Arizona, Colorado, New Mexico, Texas (West of Pecos River)
Region VII. Washington, Oregon, Idaho, Montana, Wyoming, North Dakota, South Dakota, Nebraska

Since the basic data in the 1949 A.S.E.E. survey were obtained directly from officials of the 123 engineering schools represented, whereas the 1952 E.J.C. data were obtained from questionnaires sent in directly by the individual faculty members, it was necessary to determine whether or not there were significant differences in the institutions represented in the two surveys. Fortunately more than 90% of the E.J.C. questionnaires included the name of the institution; consequently, it was possible to make this comparison.

After careful analysis, it appeared that in Regions II to VII inclusive, the institutional representation in the two surveys was reasonably comparable. In Region I, however, it appeared that two relatively important institutions were inadequately represented in the E.J.C. survey, and the analysis subsequently made shows that the upper quartile and median salaries for Region I in the E.J.C. survey, which are skewed downward, *are not truly representative of this region.*

Two other factors deserve mention. First, the E.J.C. questionnaire did not provide a space to indicate whether or not the individual was on a full-time or part-time basis. A qualitative study of the data indicates that the great majority of those replying were on a full-time basis. There were an appreciable number of questionnaires, however, which reported a very high total income coupled with a relatively low basic teaching salary. It seems likely that many of these persons were on a part-time basis although not so indicated.

Secondly, there appeared to be some confusion as to what was meant by the question: "How many months did this basic salary cover?" Again speaking qualitatively, it seemed that some persons replying "12 months" were actually on

a 10-month basis but paid in 12 installments.

I do not believe that errors introduced by the above two factors had a significant effect upon the tabulated overall results, but they may well account for some of the minor variations from the anticipated norms.

The questionnaires were sorted by academic rank and geographical region, and the upper quartile, median, and lower quartile for each classification were determined. Tabulations were made for both the ten-months base pay and for the total engineering income.

The data were then re-sorted by academic rank and by year of baccalaureate degree, and quartile tabulations were made for total engineering income within each academic rank.

Finally an overall tabulation of both base salary and total income versus year of graduation was made to provide a comparison with the corresponding tabulations compiled independently by the E.J.C. and presented in their report entitled "Professional Income of Engineers –1953."

Calculations were made of the percentage distribution of questionnaires by rank, region, and year of graduation as an aid in evaluating the reliability of the results of the salary study.

And lastly the ratio of the ten-months' base pay to the total engineering income was calculated for each quartile by rank and region to determine whether or not a significant relationship exists between them.

The results are presented graphically in the body of the report; the detailed tabulations are given in the appendix.

Individual Distribution of Questionnaires

As previously indicated, a qualitative study of the questionnaires revealed that returns from Region I were inadequate to provide a reliable index of salaries in that region. For the country as a whole, however, the E.J.C. regional distribution as shown in Figure 1 appears to be reasonably comparable with that of the 1949 A.S.E.E. survey.

The distribution by academic rank presents quite a different picture. Whereas in 1949, full professors accounted for only 21% of the total, in 1953 this figure had increased to 35%. And whereas instructors in the A.S.E.E. study comprised 39% of the total, in the E.J.C. survey, they number only 12%. This shift in rank distribution is shown in Figure 1. Whether this represents a major up-grading in terms of rank or whether it is an indication that the E.J.C. data are not in fact a representative cross-section of engineering educators, is difficult to determine from the information at hand.

Referring to Figure 2, the age distribution (as indicated by the year of graduation) both overall and within each rank seems to follow a reasonable pattern. The A.S.E.E. survey did not include complete data on age distribution, but the average ages of staff members were estimated to be as follows: professors—49 years, associate professors—44 years, assistant professors—36 years, instructors—30 years. Assuming the median age at year of graduation to be 23 years, the present study (see Fig. 2) gives approximate average ages as follows: professors—49 years, associate professors—39 years, assistant professors—33 years, instructors—28 years. It, therefore, appears that the average age in each rank except full professor is appreciably lower than it was five years ago. This would seem to support the conclusion that there has occurred a substantial up-grading in terms of academic rank during this period and that there actually are fewer engineering teachers with the rank of instructor than there were in 1949.

Furthermore, since the age distribution within each rank as shown in Figure 2 approximates reasonably well the normal bell-shaped curves, it would seem that regardless of the over-all distribution by

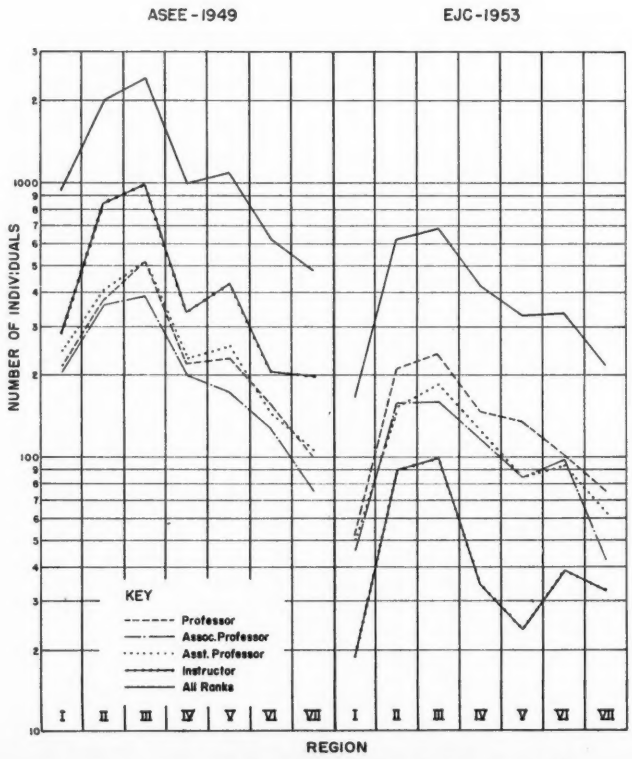


FIG. 1. Academic Rank Distribution—ASEE vs. EJC

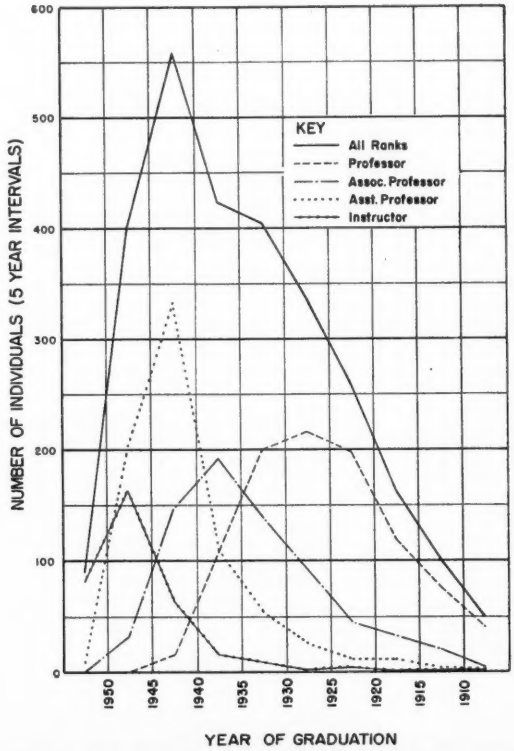


FIG. 2. EJC distribution by year of baccalaureate degree

EJC 1953
ASEE 1949

EJC 1953
ASEE 1949

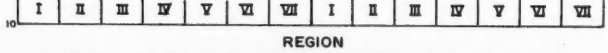


FIG. 1. Academic Rank Distribution—ASEE vs. EJC

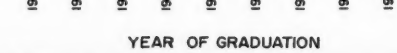


FIG. 2. EJC distribution by year of baccalaureate degree

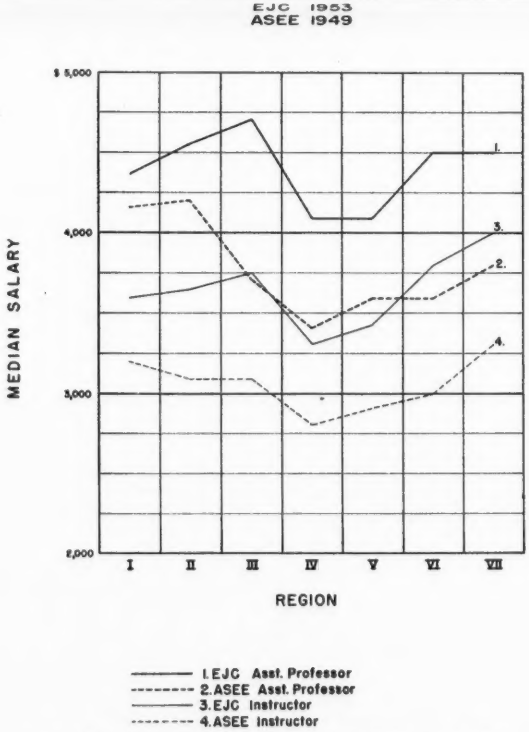


FIG. 3A. Ten-months' base pay—ASEE vs. EJC

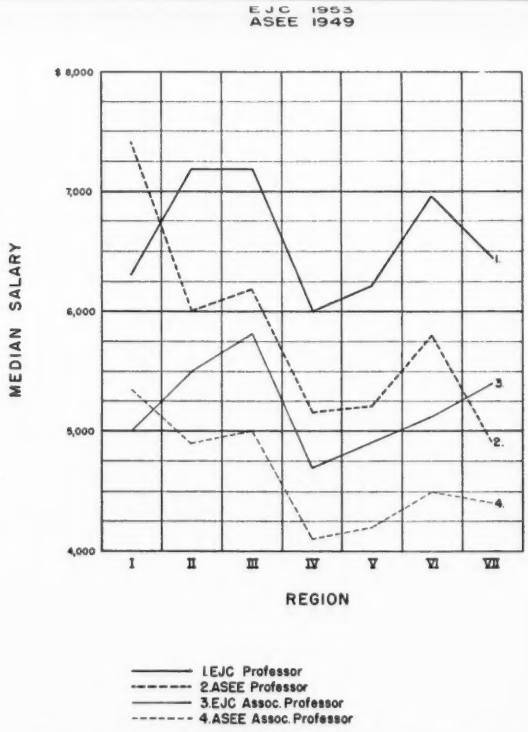


FIG. 3B. Ten-Months' Base Pay—ASEE vs. EJC

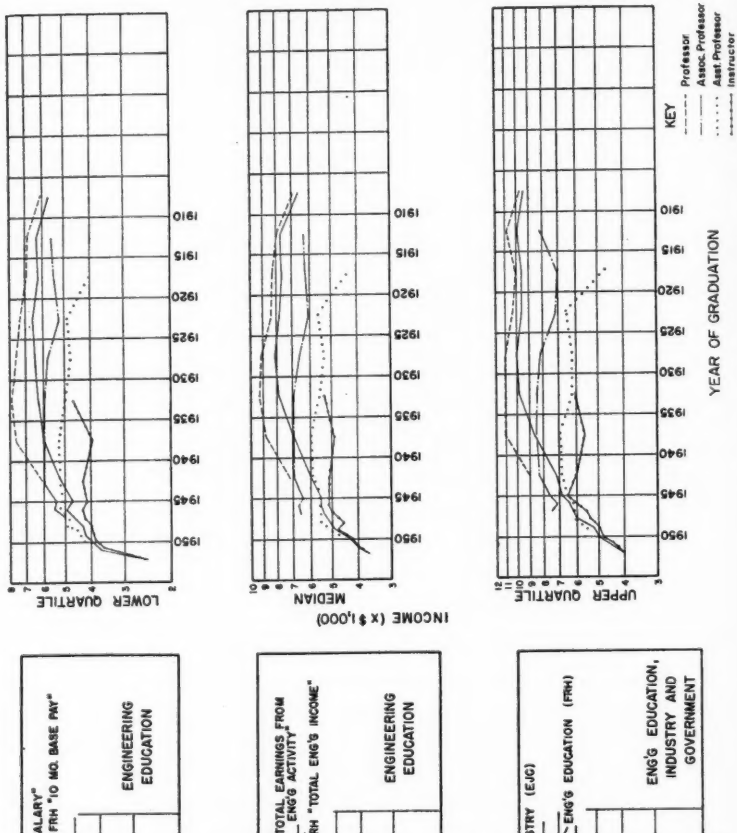


FIG. 5. Total engineering income

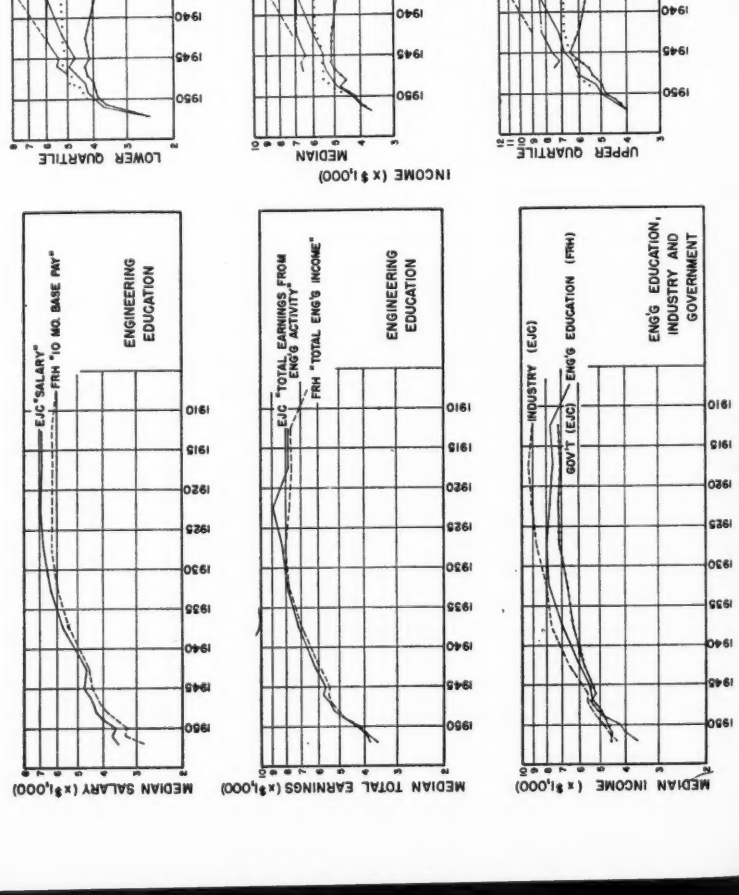


FIG. 4. This study vs. EJC Report

rank, the data for each rank separately are reasonably representative, and that comparisons, rank by rank, with the A.S.E.E. survey are statistically valid.

If our present survey is reasonably representative, and there has in fact been a substantial shift in rank distribution since 1949, rank by rank comparison will tend to minimize increases among the younger men attributable to more rapid promotion than normal.

On the other hand, even if our sample is actually skewed upward in terms of rank, overall comparisons with engineers in industry and government in terms of year of baccalaureate degree seem valid since this overall age distribution as shown in Figure 2 appears to be reasonably normal.

Comparison with 1949 A.S.E.E. Survey

Since the data for the A.S.E.E. survey were obtained from institutions whereas the E.J.C. data were obtained from individuals, it appeared that the only valid comparison which could be made would be that between individual media.

Data on individual media salaries (ten-month base pay) were, therefore, plotted by geographical regions and by academic ranks, and the results are shown in Figures 3. Except for Region I (where we know the data are not representative and are skewed downward) a remarkably consistent pattern is revealed showing a substantial increase in base salary in all ranks and regions. Country-wide this increase amounts to 20% from 1948 to 1952 and compares with an increase of about 13% in the cost of living index * for the same period.

We are all aware that in the years following the close of World War II, the cost of living increased very sharply, and teaching salaries increased relatively slowly. It appears that during the past few years, salaries have continued to rise, and the gap between income and cost of living has been narrowed appreciably.

Comparison with the General E.C.J. Survey

The E.J.C. report entitled "Professional Income of Engineers—1953," recently published, contains a number of tabulations showing the upper quartile, median, and lower quartile salaries for engineers in education, government, and industry arrayed according to the year of baccalaureate degree. Two tables for engineering education are given in the E.J.C. Report: Table XIX covers "Basic Teaching Salary" and Table XX covers "Total Income of Engineering Educators."

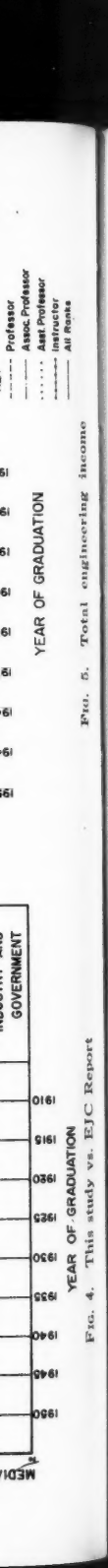
Although my tabulations were made from the same basic data, they differed from the E.J.C. results in two respects. First, I eliminated questionnaires from deans and from persons engaged entirely in research. Secondly, I adjusted all basic salaries to the ten-months' basis. It seemed desirable, therefore, to compare these with the E.J.C. tabulations.

A word of caution is perhaps in order at this point concerning the visual comparison of the graphs in the E.C.J. report and those in this report. Inasmuch as entirely different scales were used for plotting both ordinates and abscissae, the appearance of the corresponding graphs in the two reports is quite different. I have tried in this report to plot the data in a way to bring out visually what seem to be significant variations.

Figure 4 shows a comparison of median figures as compiled by E.J.C. with the new computations. It will be observed that the adjusted "Ten-Months' Base Pay" figures (upper chart) are appreciably lower than the E.J.C. "Basic Teaching Salary" figures. The two graphs for "Total Income" (middle chart) agree very closely except for the period 1920–1924. I suspect that there may be a typographical error in the E.J.C. data for that period.

The lower chart on Figure 4 shows a

* Consumers Price Index—Bureau of Labor Statistics.



comparison of total earnings in engineering education versus salaries in industry and government. It is recognized that the latter are perhaps not identical with total engineering income, but common experience would suggest that the differences are no so great as to invalidate a qualitative comparison. This chart bears out the generally accepted opinion that by and large industry pays better than teaching or government service. This chart also suggests that the older educators have fared less well than their younger colleagues, so that a further study of income in relation to age and academic rank has been made.

Figure 5 shows the total engineering income for each professorial rank plotted against the year in which the men received their baccalaureate degrees. This seems to indicate that the younger men have forged ahead of their older associates in all ranks, and the pattern is the same for the upper quartile, median, and lower quartile. Perhaps the economic pressure upon the younger men with growing families in a period of rising prices has been more severe than for the older men whose children are now established on their own.

Relationship Between Base Salary and Total Income

The 1949 A.S.E.E. survey did not attempt to evaluate the relationship between the ten-months' base salary and total income for the year. The importance of this relationship is obvious particularly in making comparisons with salaries paid in industry and government. The E.J.C. questionnaires did, however, furnish data on both base salary and total income, and quartile tabulations of both by rank and region were made as previously indicated. It was, therefore, a simple matter to calculate the ratio of base salary to total income for each quartile in each rank and region. The results were surprisingly consistent throughout, and the median of the medians was found to be 78%.

In order to verify this computation, the median figures for total engineering income were multiplied by 78%, and these values were plotted along with the actual medians for the corresponding ten-months' base salaries. The results clearly indicated close correlations between base pay and total income.

There seems to be no significant variation from the norm among the various academic ranks; the variations in the rank of instructor are attributed to the small size of the sample.

There does seem to be a slight variation regionally. As might be expected, total income is slightly above the norm in Region II where opportunities for consulting work are plentiful, and it is slightly below the norm in Region VII where consulting opportunities are probably less readily available.

The variation in terms of age (or year of graduation) bears out the hypothesis that economic pressure on the younger men has forced them to supplement their salaries to a larger extent than their older colleagues have found necessary.

As an overall yardstick, nevertheless, I believe it is reasonably accurate to conclude that the ten-months' base salary for engineering educators constitutes from 3/4 to 4/5 of the total annual earned income.

Summary

The following general observations seemed warranted from this brief analysis of the questionnaires submitted by engineering educators to E.C.J. in 1953.

Academic Rank

There seems to have been a substantial change in the percentage distribution of engineering teachers in the four academic ranks. Today there appear to be fewer instructors and more full professors than there were in 1949. In order to be sure of this trend, however, it would be necessary to obtain current data comparable to that of the 1949 A.S.E.E. Report.

Teaching Salaries

Salaries in all ranks have generally increased by about 20% in the period from 1948 to 1952. This compares with an increase of about 13% in the cost of living during the same period. Younger faculty members have in general obtained larger percentage increases than their older colleagues.

Engineers in industry continue to command higher salaries than do engineering educators although the differences in total income are perhaps not so large as is commonly supposed.

Basic Salary versus Total Income

In general the basic salary for the academic year of nine to ten months constitutes about 3/4 to 4/5 of the total annual income of engineering educators, this basic salary in most instances being supplemented by income from evening and summer teaching and from consulting work.

APPENDIX A

Analysis by Geographical Regions

Region	I	II	III	IV	V	VI	VII	Total
Individual Distribution—1949 (ASEE)								
Professor	216	376	520	222	232	153	101	1,820
Assoc. Prof.	206	362	387	204	173	127	77	1,536
Asst. Prof.	242	411	517	230	253	143	105	1,901
Instructor	283	845	979	340	432	206	199	3,284
Total	947	1,994	2,403	996	1,090	629	482	8,541
Individual Distribution—1953 (EJC)								
Professor	52	213	241	148	137	104	77	972
Assoc. Prof.	46	158	163	116	86	99	43	711
Asst. Prof.	50	155	186	128	85	94	64	762
Instructor	19	88	99	35	24	39	33	337
Total	167	614	689	427	332	336	217	2,782
Ten-Months Base Salary 1952–1953 (EJC)								
Professor								
Upper Quart.	7,340	8,000	8,300	6,500	7,000	8,300	7,450	
Median	6,300	7,200	7,200	6,000	6,230	6,950	6,450	
Lower Quart.	5,450	6,200	6,400	5,400	5,700	6,100	6,000	
Assoc. Prof.								
Upper Quar.	5,940	6,000	6,300	5,100	5,400	6,000	6,090	
Median	5,000	5,500	5,800	4,700	4,900	6,100	5,400	
Lower Quar.	4,600	5,000	5,020	4,400	4,580	4,700	5,000	
Asst. Prof.								
Upper Quar.	4,890	5,000	5,100	4,450	4,400	5,000	4,900	
Median	4,370	4,550	4,720	4,100	4,100	4,500	4,500	
Lower Quar.	3,900	4,200	4,200	3,750	3,800	4,090	4,200	
Instructor								
Upper Quar.	4,020	4,000	4,150	3,600	3,700	4,100	4,230	
Median	3,600	3,650	3,750	3,300	3,380	3,780	4,000	
Lower Quar.	3,300	3,250	3,500	3,000	3,000	3,480	3,710	
Total Engineering Income—1952 (EJC)								
Professor								
Upper Quar.	11,000	12,000	11,900	9,000	9,400	10,700	9,050	10,750
Median	8,050	10,000	9,600	7,700	8,000	8,550	8,000	8,680
Lower Quar.	6,640	8,200	7,840	6,640	6,850	7,300	7,100	7,280
Assoc. Prof.								
Upper Quar.	7,200	9,000	8,800	6,950	7,400	7,870	7,770	8,000
Median	6,450	7,480	7,170	6,170	6,570	6,850	6,800	6,800
Lower Quar.	5,800	6,250	6,300	5,380	5,800	5,810	5,400	5,880
Asst. Prof.								
Upper Quar.	6,000	7,500	6,800	6,000	5,770	7,000	6,340	6,500
Median	5,280	6,000	5,850	5,370	5,080	5,990	5,560	5,650
Lower Quar.	4,950	5,300	5,300	4,700	4,480	5,000	5,000	5,000
Instructor								
Upper Quar.	4,980	5,550	5,500	5,400	5,200	5,600	5,300	5,410
Median	4,400	4,720	4,660	4,500	4,810	4,800	4,800	4,700
Lower Quar.	3,700	4,000	4,000	3,500	3,720	4,000	4,100	4,000

APPENDIX B

ANALYSIS BY YEAR OF BACCALAUREATE DEGREE

Year of Degree.....	1952	1951	1950	1949	1948	1947	1946	1945	1940–1944	1935–1939	1930–1934	1925–1929	1920–1924	1915–1919	1910–1914	1909 & earlier	Total
Individual Distribution—1953 (E.J.C.)																	
Professor						1	1		15	105	201	216	198	119	76	40	972
Associate Professor		1	1	2	4	10	8	10	148	192	140	93	45	32	21	4	711
Assistant Professor		1	7	18	56	68	33	30	331	110	54	26	12	10	4	2	762
Instructor	13	16	50	54	40	34	12	21	64	16	10	1	3	1	0	1	337
Total	13	18	58	74	100	113	54	61	558	423	405	336	258	162	101	48	2782
Ten-Months Base Salary —1952–53 (E.J.C.)																	
All Ranks																	
Upper Quartile	3450	3900	3700	4000	4200	4500	4750	4700	5050	6200	7000	7500	7330	7200	7500	7370	
Median	2800	3400	3370	3630	3900	4100	4220	4400	4550	5400	6000	6270	6240	6200	6250	5950	
Lower Quartile	2100	3000	3100	3300	3600	3770	3800	3820	4100	4700	5000	5150	5400	5230	5130	4700	
Total Engineering Income —1952 (E.J.C.)																	
Professor																	
Upper Quartile									9000	11000	11000	11000	10300	10000	10750	9600	10750
Median									7200	8800	9300	9150	8340	8300	8000	6870	8680
Lower Quartile									6000	7550	7830	7550	7250	6900	6840	6080	7280
Associate Professor																	
Upper Quartile						7500	7270	7700	8350	8500	8450	8090	7100	7000	8200		8000
Median						6600	6700	6500	7000	7000	7000	6600	6100	6210	6300		6800
Lower Quartile						5000	5500	5400	6030	6000	6000	5910	5200	5370	5500		5880
Assistant Professor																	
Upper Quartile			5300	5500	6150	6260	6190	6500	6800	7000	6200	6240	6500	4600			6500
Median			4500	4950	5500	5520	5500	5500	5900	6000	5500	5310	5600	4360			5650
Lower Quartile			4230	4200	4900	4770	5140	5000	5200	5200	5000	4700	4810	4000			5000
Instructor																	
Upper Quartile	4000	4410	4900	5000	5300	5510	6100	6620	6100	5600	6070						5410
Median	3600	4000	4200	4770	4590	4960	5170	5200	5070	4940	5420						4700
Lower Quartile	2500	3520	3820	4200	4000	4200	4320	4070	4250	3940	4670						4000
All Ranks																	
Upper Quartile	4000	4530	5000	5200	6000	6260	6470	6870	7180	8700	9770	10030	9500	9500	10000	9370	8600
Median	3600	4000	4210	4800	5100	5400	5500	5500	6000	7000	7900	8120	7790	7600	7700	6590	6800
Lower Quartile	2500	3600	3850	4200	4290	4620	5000	4630	5200	5900	6260	6460	6500	6220	6270	5700	5500

APPENDIX C

1952 Total Engineering Income Distribution by Academic Rank

Academic Rank.....	Dean	Professor	Associate Professor	Assistant Professor	Instructor	Totals
$15,000 and over	7	74	8	1	1	91
14,500 14,999	0	6	0	0	0	6
14,000 14,499	1	8	0	2	0	11
13,500 13,999	1	7	0	0	0	8
13,000 13,499	1	17	2	1	0	21
12,500 12,999	2	14	0	0	0	16
12,000 12,499	2	43	12	4	0	61
11,500 11,999	2	22	5	1	0	30
11,000 11,499	3	48	8	1	1	61
10,500 10,999	6	20	9	2	0	37
10,000 10,499	5	72	25	6	0	108
9,500 9,999	4	56	18	3	0	81
9,000 9,499	2	69	30	11	1	113
8,500 8,999	0	63	31	11	0	105
8,000 8,499	3	105	51	22	6	187
7,500 7,999	7	82	56	29	1	175
7,000 7,499	2	78	85	54	12	231
6,500 6,999		74	81	57	11	223
6,000 6,499		55	106	112	22	295
5,500 5,999		34	79	126	26	265
5,000 5,499		17	59	146	49	271
4,500 4,999		6	33	95	65	199
4,000 4,499		2	12	59	63	136
3,500 3,999			1	17	48	66
3,000 3,499				2	18	20
2,500 2,999					4	4
Under 2,500					9	9
Totals	48	972	711	762	337	2830

APPENDIX D

ASEE Survey—Individual Media 1948–49 Ten-Months' Base Salary

Region.....	I	II	III	IV	V	VI	VII
Professor	7400	6000	6200	5100	5200	5800	4900
Assoc. Prof.	5300	4900	5000	4100	4200	4500	4400
Asst. Prof.	4100	4200	3700	3400	3600	3600	3800
Instructor	3200	3100	3100	2800	2900	3000	3300

THE T-SQUARE PAGE

CONTRIBUTIONS TO ENGINEERING EDUCATION
BY THE
DIVISION OF ENGINEERING DRAWING

T. T. AAKHUS, *Chairman*
University of Nebraska

HAROLD P. SKAMSER, *Secretary-Treasurer*
Michigan State College

WILLIAM E. STREET, *Vice Chairman*
A & M College of Texas

IRWIN WLADAVER, *Editor of*
the T-Square Page
New York University

Coordination

By FRANK A. HEACOCK
Princeton University

At the first SPEE Summer School in Engineering Drawing and Descriptive Geometry, conducted at the Carnegie Institute of Technology in Pittsburgh in June 1930, I was a member of committee No. 5 on the coordination of drawing and descriptive geometry courses with other courses. The chairman of this committee, Professor W. H. Kirchner of the University of Minnesota, presented on June 20, 1930 the following report:

In order to promote the coordination of drawing and descriptive geometry courses with other courses, the first requisite seems to be a realization on the part of the instructor of the place and importance of his work in the field of education. This requires a careful study and a sympathetic appreciation of the aims and accomplishments of related and allied departments. Because of the unlimited possibilities in the use of graphic means of expression and representation, no instructor is expected to gain a complete mastery of graphical science, but he should endeavor to raise his work, and at the same time himself, to a high professional plane.

A close coordination with the work in mathematics, mechanics, and experimental laboratories is decidedly advantageous to all concerned. While the alphabet and grammar of drawing are not to be neglected, it is well to remember that graphical language like written language is used to express thought. By gradual steps the mind acquires the ability to create images of magnitude, motions, structures, and the many manifestations of energy, including numerous purely hypothetical assumptions. The drawing department should present and develop this powerful means of expressing the concepts of the mind in a much more comprehensive and scholarly way, in both a scientific and an artistic manner.

The individual student should not be sacrificed in order to turn out a uniformly mediocre product. It is highly important to make sure that a student who has acquired a certain proficiency should not be allowed to "mark time," but should have his interest, imagination, and inventive faculties stimulated to further progress and higher achievement.

It is essential that allied departments keep in touch with each other to insure coordination and resulting profitable results. The study of graphics is sufficiently important to occupy a unique place of its own which should include all the styles of graphic expression, both pure and applied.

This sound teaching policy of 1930 is even more significant today. The importance of graphics as an essential part of engineering education demands thorough and well balanced graphics instruction that is effectively coordinated with other courses to provide the best working equipment for the engineers of tomorrow.

Teaching Tips

Making a Measuring Stick for a Horizontal Cylindrical Tank
A Freshman Mathematics Project

By WILLIAM K. VIERTEL

Instructor, State University Agricultural and Technical Institute, Canton, N. Y.

One of the most interesting and useful applications of trigonometry is the calculation of the volume of liquid in a horizontal cylindrical tank when the depth of liquid and the dimensions of the tank are known. This problem is an excellent one in having disciplinary value as well as practical value. The writer believes it deserves more attention than it usually gets, and has devised a project which dramatizes the problem and puts it in a way that appeals to students. It has been a part of the freshman mathematics work at this school for several years.

The project, in brief, is this: each student is asked to make a pattern for a measuring stick for a horizontal cylindrical tank of given dimensions. They are told only that the stick, if made from the pattern presented, should be convenient, accurate, and as nearly foolproof as possible for use by a workman lacking technical training.

They are shown how to calculate the volume for any given depth, working it out from basic principles. One or two assignments are then devoted to making the calculations. The results of the calculations are put in the form of a table, giving volume of liquid in gallons corresponding to regular small increases in depth. Each student takes the data and draws a graph, and from the graph he makes the pattern for the measuring stick.

Most students get the idea, and present patterns marked on long strips of paper with marks every 5 gallons, or whatever divisions are suitable for the size of tank assigned. Some are thoughtful and resourceful enough to add subdivisions to the major divisions. A few take some trouble with the workmanship, and bring in wooden sticks which would actually serve as measuring sticks.

It is believed that this project is of value, not only in providing motivation, but in helping to develop judgment.

Timely Tips

Dimensional Algebra

By W. A. GROSS

Assistant Professor, Theoretical and Applied Mechanics, Iowa State College

It has been the experience of the author that the subject of dimensional equations can be more understandingly presented by emphasizing the differences between ordinary algebra and dimensional algebra. The standard notations for the fundamental engineering quantities, F, L, and T (force, length, and time), are presented. The dimension 0 is introduced to represent no dimension and is applied to angles, functions of angles, or other dimensionless quantities.

In a homogeneous equation, every term set off by plus or minus signs or equal signs must have the same dimension. The symbol $\sim$ can be used to represent "has the same dimensions as." Hence all plus or minus signs are replaced by $\sim$ when writing the dimensional relation for an algebraic equation. This convention seems to be of great value to the student, for he is not confused by the ordinary algebraic symbols.

Powers or roots of fundamental quantities F, L, or T are allowable, as are multiplication and division. It should be noted that when a quantity is multiplied by a dimensionless constant, its fundamental dimensions remain unchanged, e.g., $0 \cdot F \sim F$, $F/0 \sim F$. This property is sufficiently startling to awaken interest and understanding in the student.

As an illustrative example, consider the equation for the steady state forced amplitude of a single degree of freedom system,

$$A = \pm \frac{P}{k} \cdot \frac{\sqrt{1 - (4F/\pi P)^2}}{1 - \omega^2/p^2}.$$

The corresponding dimensional relations may be presented in accordance with the preceding rules as follows:

$$L \sim \frac{F}{FL^{-1}} \cdot \frac{\sqrt{0 \sim (F/F)^2}}{0 \sim (T^{-2}/T^{-2})}.$$

The symbol $\sim$ together with the use of 0 shows immediately the fundamental dimensional relationships to the student. Homogeneity can be checked, or unknown dimensions rapidly determined.

Minutes of Executive Board

A meeting of the Executive Board of the ASEE was held in the Executive Board Room of the AIEE in New York City on Saturday, September 11, 1954 at 9:00 A.M. Those present included: N. W. Dougherty, *President;* W. L. Everitt, L. J. Lassalle, B. R. Teare, Jr., and H. K. Work, *Vice Presidents;* G. W. Farnham, *Treasurer;* A. B. Bronwell, *Secretary.*

Report of the Secretary

The Secretary reported that:

a. The Teaching Aids Bulletin is now in the hands of the press and will be completed in about two months.
b. The Committee on Evaluation of Engineering Education will probably meet at the time of the Land Grant College Association in Washington. This Committee expects to complete its work by June of next year. Approximately eight thousand copies of the Interim Report have been sold and an additional four thousand copies have been reordered.

Report of the Treasurer

The Annual Audit shows a net profit of $1,306 for the past year. Most expenses were held down because of the anticipated deficit. Also, ECRC expenses were abnormally low because it publishes its Directory and Review of Current Research every other year.

Reports of Vice Presidents

Vice President H. K. Work reported that the ECRC will publish its Directory and Review of Current Research again this year. It will endeavor to get out a book on Creativity in Research, which will be a compilation of papers on this subject presented at ECRC meetings. Also, ECRC is considering preparation of a small booklet on policy matters in relationships between colleges and government on government sponsored research. The theme for the General Session which the ECRC will program will by Education for Research.

ECRC has completed a study of Remuneration Policies in Research. It was suggested that this be published in the JOURNAL. Also, ECRC is appointing a new Committee on Research Administration. The ECRC will have a new Secretary, Dr. Renato Contini of New York University, starting September 1.

Vice President W. L. Everitt stated that the ECAC Executive Committee will meet during the Land-Grant College Association meeting in November; therefore, it has not planned its activities for the year as yet. ECAC is continuing its efforts in Manpower, International Relations, Selection and Guidance, and Secondary Schools.

Vice President Teare stressed the desirability of having officers attend Section Meetings. A tentative schedule of officer attendance at Section Meetings was drawn up.

Vice President Lassalle stated that at a meeting with President Dougherty, Secretary Bronwell and himself, the Committee appointments for the coming year had been prepared and letters inviting Society members to serve on Society Committees had been sent out. The Executive Board members emphasized the desirability of including on the Committees some of the younger members of the Society and suggested that the Chairman of YET be contacted for names of prospective members.

Proposed Study on Specializations in Engineering

Vice President Teare stated that there has been considerable interest from several sources in the possibility of conducting a study of Specializations in Engineering Education. The Executive Board voted the following resolution:

> The Board hereby expresses its interest in a possible study to determine whether or not the present curricular divisions and options as taught in engineering colleges provide the best plan for engineering education. It recommends that an ad hoc Committee of the Society be appointed to prepare a proposal for such a study and make recommendations regarding funds and personnel.

The ad hoc Committee will consist of B. R. Teare, Chairman, George Hawkins, and W. L. Everitt.

1955 Annual Meeting

The general framework for the 1955 Annual Meeting was discussed. The Board recommended holding three General Sessions on Tuesday, Wednesday and Thursday morning. It was recommended that there be no conferences conflicting with these General Sessions. It was also recommended that a General Session be held on Monday afternoon to present reports on principal Society activities, as in previous years, but that conferences should be scheduled concurrently with this Session.

It was suggested that the ECAC and ECRC again hold a joint dinner on Tuesday evening in view of the favorable response of last year's joint dinner.

The Board voted not to have a central theme for the Annual Meeting this year, in view of the fact a number of significant projects are shaping up in the Society. The General Session on Tuesday morning will include an address of welcome, the Presidential Address, a brief report on the revision of the Evaluation Report by Dean Grinter and a program to be arranged by Dr. Burdell and Dr. Gullette on the Humanistic-Social Project.

Graduate Study Proposal

The Secretary reported that an ad hoc Committee had been appointed to prepare a proposal for the Graduate Studies investigation. This Committee includes members of the Evaluation Committee and officers of the Graduate Studies Division in accordance with the request of the Graduate Studies Division.

Coordination of Projects

The Executive Board discussed the relationship of the various principal projects now under way, including the project on Evaluation of Engineering Education, the Humanistic-Social Research Project, and the Graduate Study Project. It was the consensus of opinion that these should proceed as independent investigations with overlapping membership on the Committees so as to benefit from the viewpoints and discussions on related projects. This would give each Committee maximum authority and responsibility, rather than subject their findings to review and veto power by some other group. Eventually, if there are major differences of opinion, it might be advisable to appoint a coordinating Committee consisting of members from the Committees involved to resolve the conflicts.

Placement Advertisements in the Journal

The question to whether or not individuals should be allowed to advertise for positions in the JOURNAL OF ENGINEERING EDUCATION was discussed. The JOURNAL now carries placement advertisements from engineering colleges but not from individuals seeking positions. It was pointed out that individual placement advertisements would provide increased service to the Society members. Several Board members expressed the opinion that the kind of individual who advertises for a position is often not the

better qualified individual and they were therefore skeptical about the ultimate value of this service. Also, since not many persons would advertise, this would represent a specialized service to a few members. After some discussion the matter was tabled.

1954 ASEE Summer Institutes

Vice-President Teare reported that the Summer Institute on Solid State Physics held at Carnegie Institute had an attendance of approximately 120 conferees. The program was well planned and a great deal of interest was expressed in the possibilities of realigning the physics material in the engineering curricula and adding more on Modern Physics and Solid State Physics. A final report of this conference will be prepared by Professor Glenn Murphy for publication in the JOURNAL. Wiley Book Company will publish the papers in book form.

The Summer Institute on Nuclear Science in Engineering Education at Northwestern University had an attendance of approximately 110 people. About one-half of these were engineering teachers and the other half physics teachers. An excellent panel of speakers was obtained and the conference indicated that reasonable results could be achieved in bringing Modern Physics and Nuclear Science into Engineering Education at several different levels. A report of this conference will be published in the JOURNAL OF ENGINEERING EDUCATION. The papers will be published either by a book publisher or in the ASEE JOURNAL.

Summer Institutes for 1955

Four summer institutes have been proposed for 1955 in the areas of: thermodynamics, advanced mathematics in engineering and science, coordination of sophomore level instruction in physics and electrical engineering, and coordination of sophomore level instruction in mechanics as taught by the physics and engineering departments. The Executive Board recommended that a committee be formed to review summer institute proposals and make recommendations to the Board.

Fellowship and Scholarship Proposals

The Secretary stated that several inquiries had been received from industries for information on the methods of setting up scholarship and fellowship programs. This raised the question as to whether or not ASEE should consider handling fellowships as a service to industry and the colleges. This would make it possible for industry to provide fellowships on an impartial basis without the necessity of setting up procedures for processing and awarding. A number of companies now provide for fellowships in specific universities, which removes the necessity of setting up methods of processing applications. However some companies would prefer to handle this on an impartial basis by some method which would select the best qualified student and let him choose which college he would prefer to attend. The Executive Board requested that this problem be referred to the committee which will handle the Graduate Studies project, with the request that this committee determine whether or not ASEE should assist companies in awarding fellowships.

It was suggested that the Secretary prepare a brief brochure of information which might be printed by ASEE describing how companies can set up fellowships in engineering colleges in the country.

EJC Activities

President Dougherty reported that the Engineers' Joint Council had held a meeting of representatives from the various constituent societies to discuss the possibility of holding a colloquium on nuclear energy during 1955. It was planned to hold such a colloquium and also to consider the role which the various engineering societies should take in this new and rapidly developing field.

EJC will hold an annual meeting, with

limited attendance, in January. The purpose will be to acquaint members of the governing boards of the constituent societies with current activities of EJC and get their views on principal EJC projects.

Summer Schools for 1955

The Secretary reported that the English and Chemical Engineering Divisions had both requested summer schools for 1955. It was requested that both Divisions supply topical outlines and budget information for consideration at the next Executive Board meeting in October.

Institutional Membership

The following institutions were voted into membership in the ASEE: Southern Technical Institute (affiliate membership), Alabama Society of Professional Engineers (associate membership), Capitol Radio Engineering Institute (affiliate membership), Keuffel and Esser Company (associate membership).

Activities of Public Relations Committee

The Public Relations Committee of ASEE presented some specific proposals for extension of its activities. These included: 1. Appointment of public relations sub-committees in ASEE Sections with recommendations for membership by the chairman of the ASEE Public Relations Committee; 2. Increasing the tenure of office of Public Relations Committee members and chairman; 3. Appointment of the chairman of the ASEE Public Relations Committee as an ex-officio non-voting member of the General Council. The Executive Board approved the first recommendation. With regard to the second recommendation it was pointed out that the President has the constitutional authority each year to appoint all committees. In general principle, however, the Board favored the second recommendation. It was recommended that the Chairman of the Public Relations Committee be invited to attend all meetings of the General Council without official appoitment.

Associate Institutional Members

It was recommended that a free copy of the ECRC Directory of Current Research and a copy of the Report on the Evaluation of Engineering Education be sent to each Associate Institutional member of the Society.

Next Executive Board Meeting

A meeting of the Executive Board will be held in Knoxville, Tennessee on April 16. The South-East Section meets at Knoxville on April 15–16. If it is necessary, an additional board meeting will be held in January, subject to call by the President.

Respectfully submitted,
ARTHUR BRONWELL, *Secretary*

Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Bucknell University	April, 1955	W. D. Garman, Bucknell University
Illinois-Indiana	University of Notre Dame	May 21, 1955	G. E. Ellithorn, University of Notre Dame
Kansas-Nebraska	University of Nebraska	Oct. 22–23, 1955	G. W. Bradshaw, University of Kansas
Michigan	Michigan State College	May 17, 1955	C. C. Sigerfoos, Michigan State College
Middle Atlantic	Brooklyn Polytechnic Institute	Dec. 4, 1954	H. N. Jenkins, Swarthmore College
Missouri-Arkansas	University of Missouri	April 2, 1955	M. M. Jones, University of Missouri
National Capital Area	Catholic University	Oct. 5, 1954	J. C. Michalowicz, Catholic University
New England	Massachusetts Institute of Technology	Oct. 9, 1954	E. R. McKee, University of Vermont
North Midwest	Michigan College of M. and T.	Oct. 8–9, 1954	C. J. Pratt, Michigan College of M. and T.
Ohio	A.F. Inst. Wright	Sept. 17–18, 1954	K. F. Sibila, University of Akron
	University of Akron	May 7, 1955	
*Pacific Northwest	Oregon State College	Spring, 1955	M. L. Jackson, University of Idaho
Pacific Southwest	University of California, Berkeley	Dec. 28–29, 1954	B. M. Green, Stanford University
*Rocky Mountain	Colorado A. & M. College	Spring, 1955	D. F. Peterson, Colorado A. and M. College
Southeast	University of Tennessee	April 14–16, 1955	H. V. Flinsch, Mississippi State College
Southwest	University of Oklahoma	April 8–9 1955	V. L. Doughtie, University of Texas
Upper New York	Cornell University	Oct. 22–23, 1954	N. A. Christensen, Cornell University

Members of the Society are welcome at all Section Meetings

* No Date Set.

New Members

ANDREWS, JOHNNIE F., Instructor in Civil Engineering, University of Arksansas, Fayetteville, Ark. L. R. Heiple, G. F. Branigan.

ASHMORE, RICHARD D., Manager, Technical Recruiting, Monsanto Chemical Company, Texas City, Texas. A. R. Wilson, R. F. McCook.

BALYEAT, RALPH E., Associate Professor of Industrial Engineering, Purdue University, Lafayette, Ind. H. T. Amrine, H. H. Young.

BANKS, ROBERT B., Lecturer in Civil Engineering, Northwestern University, Evanston, Ill. L. B. McCammon, H. P. Hall.

BECKMAN, MORRIS H., Associate Professor of Engineering Drawing, University of Wichita, Wichita, Kansas. Kenneth Rozak, M. H. Snyder.

BORDEN, ROGER R., Acting in Charge of Mechanical Engineering Department, Franklin Technical Institute, Boston, Mass. B. K. Thorogood, W. H. Perry.

BROWN, MARTIN R., JR., Instructor in Civil Engineering, Manhattan College, New York, N. Y. Brother Leo, Brother J. McCabe.

BUCH, WILLIAM G., Instructor in Mechanical Engineering, Rutgers University, New Brunswick, N. J. M. T. Ayers, C. R. G. Dougherty.

BURTON, RALPH A., Assistant Professor of Mechanical Engineering, University of Missouri, Columbia, Mo. Milo Bolstad, C. M. Sneed.

CASTELAZ, HARVEY W., Head of Refrigeration, Heat and Air Conditioning Department, Milwaukee School of Engineering, Milwaukee, Wisc. F. J. Van Zeeland, Fred Kaufmann.

CHRISTENSEN, KEITH H., Instructor in Architecture, University of Nebraska, Lincoln, Nebr. L. B. Smith, E. B. Meier.

CORKILL, PHILIP A., Instructor in Architecture, University of Nebraska, Lincoln, Nebr. L. B. Smith, E. B. Meier.

DANTONA, LEO R., Instructor in Mathematics, Franklin Technical Institute, Boston, Mass. W. H. Perry, Jr., B. K. Thorogood.

DAVIS, DALE S., Professor of Chemical Engineering, Virginia Polytechnic Institute, Blacksburg, Va. J. W. Whittemore, W. A. Murray.

DAWSON, JAMES K., Instructor in Descriptive Geometry and Engineering Drawing, Colorado School of Mines, Golden, Colo. A. P. Wichmann, J. M. Coke.

EGRY, C. ROBERT, Professor of Industrial Engineering, University of Notre Dame, Notre Dame, Ind. H. E. Ellithorn, C. C. Stevason.

EKEY, DAVID C., Assistant Professor of Industrial Engineering, Pennsylvania State University, State College, Pa. C. E. Bullinger, R. S. Paffenbarger.

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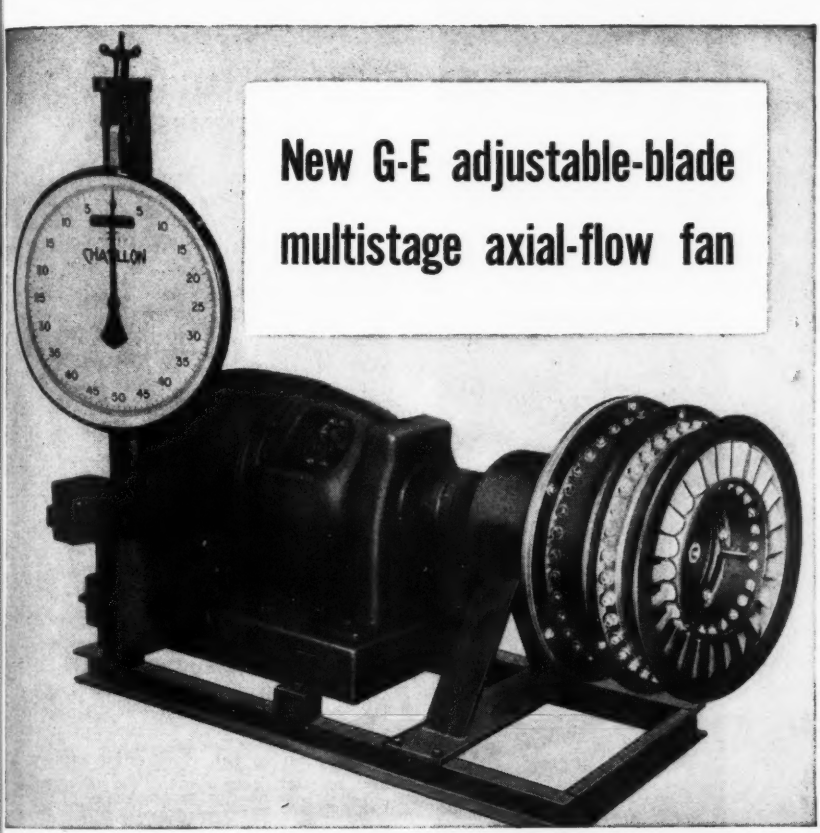

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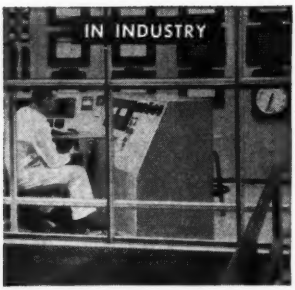

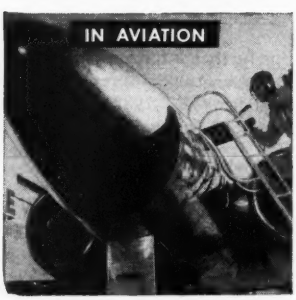

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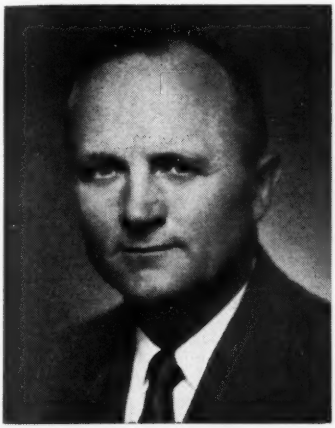

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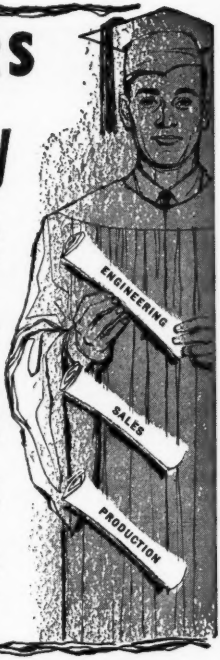

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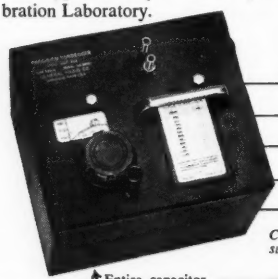

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$205	0 to 105	±0.1% ±0.2 $\mu\mu f$	±0.1% or ±0.08 $\mu\mu f$*	±0.1% or ±0.02
722-ME	0 to 105	±0.1% ±0.2 $\mu\mu f$	±0.1% or ±0.08 $\mu\mu f$*	±0.1% or ±0.02
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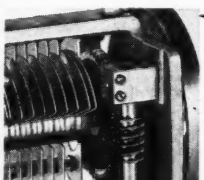

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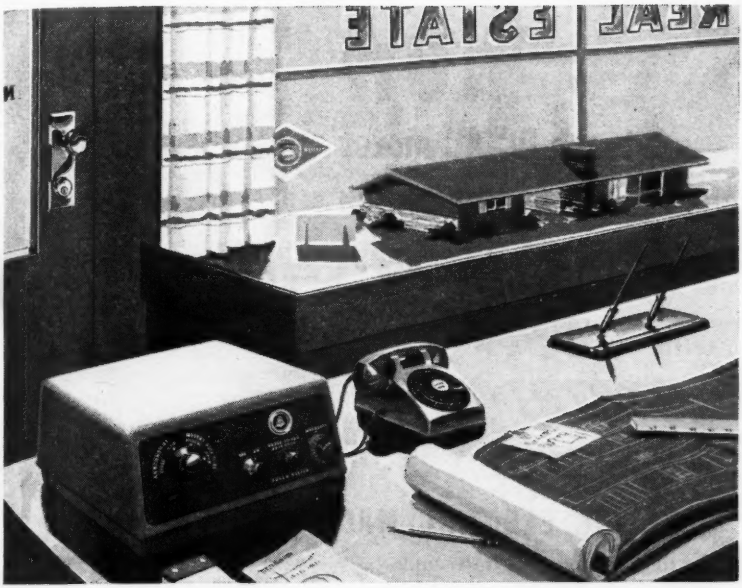

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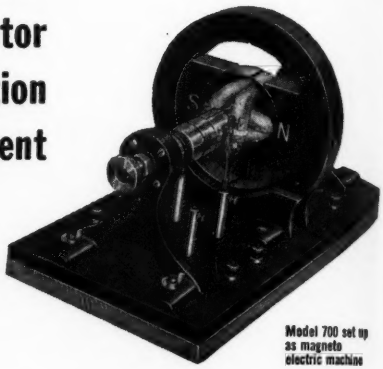

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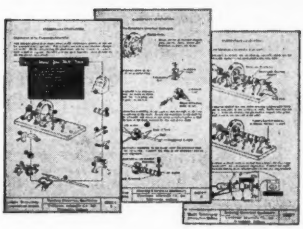

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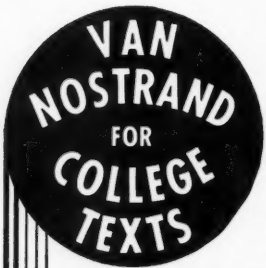

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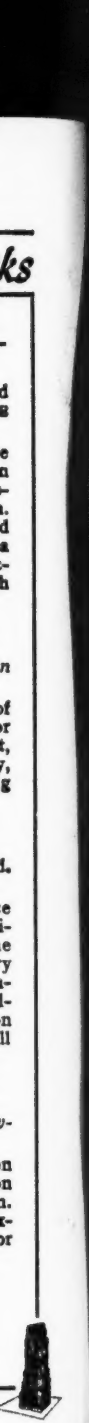
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